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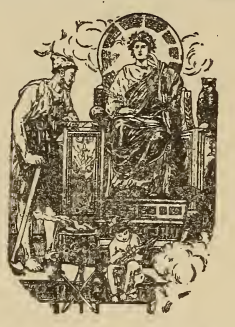

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INDEXED.

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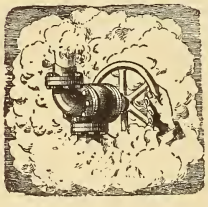

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INDEX TO VOLUME XXVIII.

		Page
Accident-Preventing Devices in America,	George E. Walsh,	223
Accidents, The Unexpected in Railway,		327
Africa, Opening the Victoria Bridge in South,		518
Air, Filtering and Washing,		514
Alcohol for Light and Power in South America,		429
Alloys and Metals, Low Temperature Experiments with,		246
Alloys, Ferro, Illustrated.	Auguste J. Rossi,	360
America, Alcohol for Light and Power in South,		429
American Petroleum Discoveries, The Latest, Illustrated.	Day Allen Willey,	370
Anæsthetic in Dentistry, Blue Light as an,		429
Astaki Fuel in Russia		519
Atmospheric Moisture, Trouble from,		331
Auto-Boat Racing,		517
Automobile Fire Engines, Illustrated.	George Glendon,	91
Automobile Racing,		515
Automobiles, Dustless,		516
Benjamin, C. H.: Planing Machine Drives, Illustrated.		125
Biographies:		
Barrus, George Hale,		163
Chaffee, J. Irvin,		87
Gibbs, George,		335
Sahlin, Axel,		248
Van Vleck, John,		519
Blast-Furnace Gas, Cleaning, Illustrated.	Axel Sahlin,	435
Blast Furnace, Iron Ore Briquettes for the, Illustrated.	Henry Louis,	227
Blue Light as an Anæsthetic in Dentistry,		429
Boat Racing, Auto-,		517
Boiler Plates; Effects of Overheating and Rolling at Too High a Temperature,		517
Boilers in the Navy, Smokeless,		329
Boilers Worked by Waste Heat from Coal-Fired Reverberatory Furnaces, Steam, Illustrated.	The Late R. T. Cooke and Percival Cooke,	397
Boiler Tubes, A New Use for Old,		333
Bridge in South Africa, Opening the Victoria, Illustrated.		518
Bridge, Making the Cables of a Large Suspension, Illustrated.	Isaac Harby,	3
Briquettes for the Blast Furnace, Iron Ore, Illustrated.	Henry Louis,	227
British High-Speed Steam Engines, Modern, Illustrated.	Leo H. Jackson,	269, 407, 509

		Page
Buildings, The Utility of Portable, Illustrated.	Arthur Fage,	119
Buildings, The Water Supply of Country, Illustrated.	Wm. Paul Gerhard,	63, 135
Business Management,		162
Cables of a Large Suspension Bridge, Making the, Illustrated.	Isaac Harby,	3
Canada, The Development of,	James Douglas,	151
Capital and Labour, The Truce Between, Illustrated.	Carroll T. Fugitt,	339
Carelessness, The Disease of,		431
Cars as Trunk Railway Feeders, Motor,	George E. Walsh,	301
Cars in Great Britain, Rail Motor, Illustrated.	J. F. Gairns,	381, 453
Centrifugal Pumps, Types of, Illustrated.	Wm. O. Webber,	154
City Fire Protection, High Pressure Systems for,	Albert Blauvelt,	420
Clay for Kindling Fires, Refractory,		514
Clocks, Sun Dials and Water,		332
Coal Resources, Great Britain's,		84
Collisions, How to Prevent End-On Railway Train,		330
Compressed Air Pipe Lines, Preventing the Freezing Up of,		161
Compressed Air Railway System, A, Illustrated.	C. B. Hodges,	466
Compressed Air Whistles,		245
Continental Machine Tools at the Liege Exhibition, Illustrated.	Joseph Horner,	479
Country Buildings, The Water Supply of, Illustrated.	Wm. Paul Gerhard,	63, 135
De Laval Steam Turbine in America, The, Illustrated.	John L. Mohun,	103
Dentistry, Blue Light as an Anæsthetic in,		429
Development of Canada, The,	James Douglas,	151
Disease of Carelessness, The,		431
Drill, A Gasoline-Motor-Driven Rock,		246
Dustless Automobiles,		516

ELECTRICITY:

Extracting Gold from Sea Water,		160
Measurement of High Temperatures, The,	H. S. Knowlton,	282
Electric Lamp Fire Dangers,		513
Motor Driving, Some Problems in,	H. S. Knowlton,	100
Heating Aboard Ship		162
Inspecting Plants for Fire Risk,	George L. Clark,	243
Power Development in Mexico, Illustrated.	Francis O. Blackwell,	171
Power Plants, Uniform Equipment in,	H. S. Knowlton,	450
Traction for Main Lines of Railways,	W. E. Langdon,	77
Energy in the Discharge of Modern Ordnance,		245
Engineering Colleges, Mathematics in,	J. B. Stanwood,	148
Engineering Personnel in the U. S. Navy,	William Ledyard Cathcart,	496
Engineer, The Province of the Industrial,	H. F. J. Porter,	511
Engine Ever Built, The Most Economical Steam,		328
Engine for an Isolated Plant, Choosing an,	H. S. Knowlton,	213

PAGE

Ether Vibrations, The Physiological Effects of Light Waves and Other, . . 429
Excavating Machine, A New Form of, . . . D. A. Willey, . . 239
Illustrated.
Exhaust Gases, Utilizing the Waste Heat of Gas and Oil Engine, . . 431
Factory Fire Drills, ... H. F. J. Porter. . . 277
Illustrated.
Feeders, Motor Cars as Trunk Railway, . . George E. Walsh, . 301
Ferro Alloys, ... Auguste J. Rossi, . 360
Illustrated.
Filtering and Washing Air, ... 514
Fire Drills, Factory, ... H. F. J. Porter, . . 277
Illustrated.
Fire Engines, Automobile, ... George Glendon, . 91
Illustrated.
Fire Engines, Self-Propelled, ... 327
Fire Protection, High-Pressure Systems for City, . Albert Blauvelt, . 420
Fire Risk, Inspecting Electric Plants for, . . George L. Clark, . 243
Fires, Refractory Clay for Kindling, ... 514
Freezing Up of Compressed Air Pipe Lines, Preventing the, ... 161
Fuel in Russia, Masut, ... 519
Fuel Reserves, Peat as One of the World's, ... 163
Furnace Gas, Cleaning Blast-, . . . Axel Sahlin, . . 435
Illustrated.
Furnace Heating, Gas for Hot Air, ... 334
Furnaces, Steam Boilers Worked by Waste Heat from
Coal-Fired Reverberatory, ... The Late R. T. Cooke
Illustrated. and Percival Cooke, 397
Gas, Cleaning Blast-Furnace, ... Axel Sahlin, . . 435
Illustrated.
Gases, Utilizing the Waste Heat of Gas and Oil Engine Exhaust, . . 431
Gas for Hot Air Furnace Heating, ... 334
Gasoline-Motor-Driven Rock Drill, A, ... 246
Gas Producer Plants, Suction, ... Dr. Oskar Nagel, . 392
Illustrated.
German Regulations Concerning Public Spark-Telegraphy, ... 247
Gold from Sea Water, Electrically Extracted, ... 160
Grain Storage and Manipulation at the Quayside, . Brysson Cunningham, 40
Illustrated.
Harby, Isaac: Making the Cables of a Large Suspension Bridge, . . . 3
Illustrated.
Heat from Coal-Fired Reverberatory Furnaces, Steam
Boilers Worked by Waste, ... The Late R. T. Cooke
Illustrated. and Percival Cooke, . 397
Heating Aboard Ship, Electric, ... 162
Heating, Gas for Hot Air Furnace, ... 334
Heat of Gas and Oil Engine Exhaust Gases, Utilizing the Waste, . . . 431
Incandescent Lamp Abuses, ... 81
Industrial Engineer, The Province of the, . . H. F. J. Porter, . 511
Inspecting Electric Plants for Fire Risk, . . George L. Clark, . 243
Instruments of Measurement, Small, . . . Joseph Horner, . 30
Illustrated.
International Railway Congress, The, ... 161
Iron Mining, Large Steam Shovels in, ... 432

		PAGE
Iron Ore Briquettes for the Blast Furnace, Illustrated.	Henry Louis,	227
Iron Pipe Plumbing,		333
Isolated Plant, Choosing an Engine for an,	H. S. Knowlton,	213
Kindling Fires, Refractory Clay for,		514
Labour, The Truce Between Capital and, Illustrated.	Carroll T. Fugitt,	339
Locomotives, Mechanical Stokers for,		428
Lamp Abuses, Incandescent,		81
Lathes, High-Speed, Illustrated.	Joseph Horner,	304
Liege Exhibition, Continental Machine Tools at the, Illustrated.	Joseph Horner,	479
Light and Power in South America, Alcohol for,		429
Light as an Anæsthetic in Dentistry, Blue,		429
Light Waves and Other Ether Vibrations, The Physiological Effects of,		429
Machine Drives, Planing, Illustrated.	C. H. Benjamin,	125
Machine Shop Roofs, Illustrated.	John E. Sweet,	299
Machine Tools at the Liége Exhibition, Continental, Illustrated.	Joseph Horner,	479
Machine Tools, Some Powerful Modern,		246
Management, Business,		162
Marine Steam Turbine, The Future of the,		83
Masonry, Notes on Stone,	Charles Arthur Hague,	114
Masut Fuel in Russia,		519
Mathematics in Engineering Colleges,	J. B. Stanwood,	148
Measurements of High Temperatures, The Electrical,	H. S. Knowlton,	282
Measurement, Small Instruments of, Illustrated.	Joseph Horner,	30
Mexico, Electric Power Developments in, Illustrated.	Francis O. Blackwell,	171
Mining, Large Steam Shovels in Iron,		432
Moisture, Trouble from Atmospheric,		331
Motor Cars as Trunk Railway Feeders,	George E. Walsh,	301
Motor Cars in Great Britain, Rail, Illustrated.	J. F. Gairns,	381, 453
Motor Driving, Some Problems in Electric,	H. S. Knowlton,	100
Motor Vehicles, Commercial, Illustrated.	J. F. Gairns,	193, 284
Navy, Engineering Personnel in the U. S.,	William Ledyard Cathcart	496
Navy, Smokeless Boilers in the,		329
Ordnance, Energy in the Discharge of Modern,		245
Painting Steamships,		247
Paper Mills, Steam Engineering in,	E. S. Farwell,	26
Peat as One of the World's Fuel Reserves,		163
Petroleum Discoveries, The Latest American, Illustrated.	Day Allen Willey,	370
Physiological Effects of Light Waves and Other Ether Vibrations, The		429
Planing Machine Drives, Illustrated.	C. H. Benjamin,	125
Plumbing, Iron Pipe,		333
Portable Buildings, The Utility of, Illustrated.	Arthur Fage,	119

PAGE

PORTRAITS:

Barrus, George Hale, ... 90
Chaffee, J. Irvin, ... 2
Gibbs, George, ... 250
Reuleaux, Franz, ... 515
Sahlin, Axel, ... 170
Van Vleck, John, ... 434
Watt, James, ... 338

Power in South America, Alcohol for Light and, ... 429
Power Plants, Uniform Equipment in Electric, . H. S. Knowlton, . 450
Problems in Electric Motor Driving, Some, . . H. S. Knowlton, . 100
Protection, High-Pressure Systems for City Fire, . Albert Blauvelt, . 420
Pumps, Types of Centrifugal, ... Wm. O. Webber, . 154
Illustrated.

Racing, Auto-Boat, ... 517
Racing, Automobile, ... 515
Rail Motor Cars in Great Britain, . . . J. F. Gairns, . 381, 453
Illustrated.

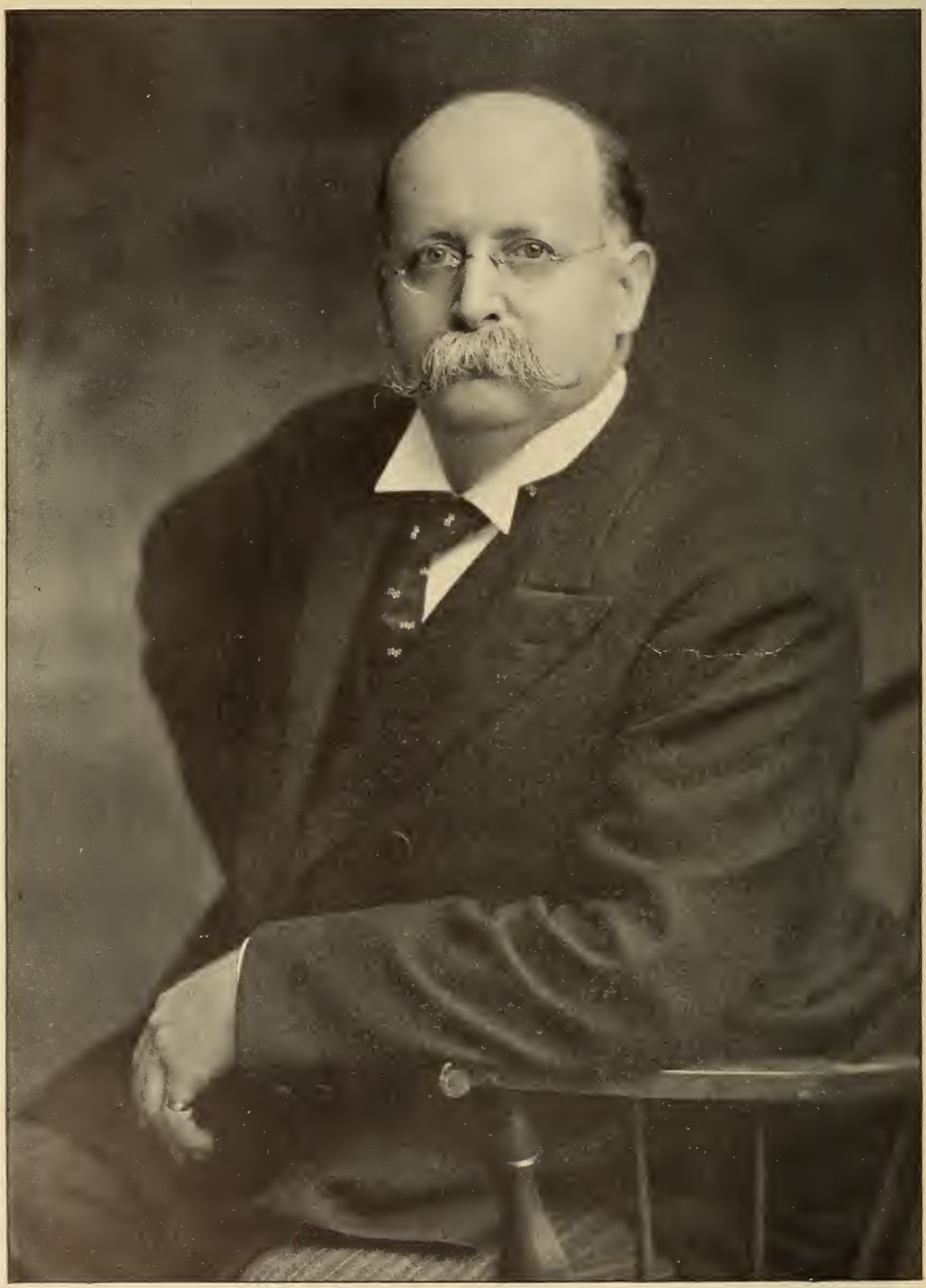
Railway Accidents, The Unexpected in, ... 327
Railway Coaches, Steel,, ... 330
Railway Congress, The International, ... 161
Railway Feeders, Motor Cars as Trunk, . . George E. Walsh, . 301
Railway, The Nerves of a, ... Day Allen Willey, . 251
Illustrated.

Railway Train Collisions, How to Prevent End-On, ... 330
Railway Travel, Safety in American, . . Day Allen Willey, . 55
Railways, Electric Traction for Main Lines of, . . W. E. Langdon, . 77
Railways, High Speeds on, ... 326
Railway System, A Compressed Air, . . . C. B. Hodges, . . 466
Illustrated.

Reuleaux, Franz, Death of, ... 514
Rock Drill, A Gasoline-Motor-Driven, ... 246
Rock Tunneling, An Ancient Example of, ... 82
Roofs, Machine Shop, ... John E. Sweet, . . 299
Illustrated.

Russia, Masut Fuel in, ... 519
Safety in American Railway Travel, . . . Day Allen Willey, . 55
Scaling Up of Water Pipes and Jackets, ... 163
Sea Water, Electrically Extracted Gold from, ... 160
Ship Bottoms, Painting, ... 85
Ship, Electric Heating Aboard, ... 162
Shop Roofs, Machine, ... John E. Sweet, . 299
Illustrated.
Shovels in Iron Mining, Large Steam, ... 432
Smokeless Boilers in the Navy, ... 329
Spark-Telegraphy, German Regulations Concerning Public, ... 247
Speeds on Railways, High, ... 326
Steam Boilers Worked by Waste Heat from Coal-Fired Reverberatory Furnaces, ... The Late R. T. Cooke and Percival Cooke, 397
Illustrated.
Steam Engineering in Paper Mills, . . . E. S. Farwell, . . 26
Steam Engine Ever Built, The Most Economical, ... 328
Steam Engines, Modern British High-Speed, . Leo H. Jackson, 269, 407, 500
Illustrated.

		PAGE
Steamships, Painting,		247
Steam Shovels in Iron Mining, Large,		432
Steam Turbine in America, The De Laval, Illustrated.	John L. Mohun,	103
Steam Turbine, The Future of the Marine,		83
Steel Boiler Plates, Effects of Overheating and Rolling at Too High a Temperature,		517
Steel Railway Coaches,		330
Stokers for Locomotives, Mechanical,		428
Stone Masonry, Notes on,	Charles Arthur Hague,	114
Suction Gas Producer Plants, Illustrated.	Dr. Oskar Nagel,	392
Suggestion System, The, Illustrated.	H. F. J. Porter,	218
Sun Dials and Water Clocks,		332
System, The Suggestion, Illustrated.	H. F. J. Porter,	218
Telegraphy, German Regulations Concerning Public Spark,		247
Temperature Experiments with Alloys and Metals, Low-,		246
Temperatures, The Electrical Measurement of High,	H. S. Knowlton,	282
Tools at the Liége Exhibition, Continental Machine, Illustrated.	Joseph Horner,	479
Truce Between Capital and Labour, The, Illustrated.	Carroll T. Fugitt,	339
Tunneling, An Ancient Example of Rock,		82
Turbine in America, The De Laval Steam, Illustrated.	John L. Mohun,	103
Turbine, The Future of the Marine Steam,		83
United States Navy, Engineering Personnel in the,	William Ledyard Cathcart	496
Vehicles, Commercial Motor, Illustrated.	J. F. Gairns,	193, 284
Victoria Bridge in South Africa, Opening the, Illustrated.		518
Washing Air, Filtering and,		514
Waste Heat from Coal-Fired Reverberatory Furnaces, Steam Boilers Worked by, Illustrated.	The Late R. T. Cooke and Percival Cooke,	397
Water Clocks, Sun Dials and,		332
Water Pipes and Jackets, Scaling up of,		163
Water Supply of Country Buildings, The, Illustrated.	Wm. Paul Gerhard,	63, 135
Whistles, Compressed Air,		245



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SEE PAGE 87

INDEXED

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MAKING THE CABLES OF A LARGE SUSPENSION BRIDGE

By Isaac Harby, Assoc. M. Am. Soc. C. E.

THE science and art of suspension bridge cable building has occupied a comparatively small place in the field of engineering accomplishments of the period. The demand for large suspension bridges has been so limited that there are very few engineers who have ever been called upon to display their skill in that direction. There is scarcely a branch of engineering, however, which demands more use of the higher mathematics, requires more intricate or broader mathematical treatment, and calls forth more originality of execution than the design and erection of a set of cables for a large suspension bridge.

The Williamsburgh Bridge, spanning the East River and connecting New York with what is known as the Williamsburgh section of Brooklyn, is the newest of the large bridges of the world, and its cables are over 50 per cent. larger and stronger than those of the original Brooklyn Bridge, which, until recently, had enjoyed the distinction since its completion, twenty-two years ago, of being the largest of all suspension bridges. This being a period of great accomplishments, it is not to be wondered at that each new effort should surpass the old. The new bridge is about a mile north of the Brooklyn Bridge. Not content, however, with this achievement, the city of New York is now building the third suspension bridge across the East River. It will be known as the Manhattan Bridge, and will occupy a place between the Brooklyn Bridge and the Williamsburgh Bridge. While the span will be about 130 feet less, the cables are to be one-third larger than those of the Williamsburgh Bridge.

The principle employed in the building of wire cables for this type of bridge has not materially changed since 1844, when John A. Roebling invented the "spinning in the air" process, and employed it in the building of cables to support an aqueduct across the Allegheny River. All the large suspension bridge cables built in this country since that time have been made after practically the same method. It is the only one known by means of which large wire cables can be successfully constructed. The notable examples of this are the International Railway Suspension Bridge over the Niagara River (since rebuilt into a steel arch) of 800-foot span, finished in 1854, designed and built by John A. Roebling; the Cincinnati and

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FIG. 1.—THE FOOT BRIDGES SEEN FROM THE TOP OF THE BROOKLYN TOWER

FIG. 2.—THE FOOT BRIDGE USED IN CONSTRUCTING THE CABLES

Covington Bridge over the Ohio River, 1000-foot span, completed in 1866, designed and built by John A. Roebling; the Brooklyn Bridge, span 1595 feet, completed in 1883, designed by John A. Roebling, built by his son, Col. Washington A. Roebling; two cables added to the Cincinnati and Covington Bridge in 1900 by William Hildenbrand; and the Williamsburgh Bridge, span 1600 feet, completed in 1904, designed by L. L. Buck, cables built by William Hildenbrand, chief engineer for John A. Roebling's Sons Company, under the direction of C. G. Roebling.

Some decided advances in the art were made when the Williamsburgh Bridge cables were built. These consisted principally of contrivances by means of which the time for building the cables could be shortened. The success of these can best be judged by a comparison of time with similar work done on the Brooklyn Bridge. The time consumed from the stretching of the first rope between towers until the running of the first cable wire was ten months in the Brooklyn Bridge, and seven months in the Williamsburgh Bridge. The time required for stringing wires was twenty-one months for the Brooklyn Bridge, and seven months for the Williamsburgh Bridge. The maximum amount of wire stretched in one day was $19\frac{1}{2}$ and 75 tons, respectively.

For the above reason, and because suspension bridge cable building is so lightly treated of in technical literature, a rather detailed description of the work on the Williamsburgh Bridge is given here, with the hope that it will prove of value to those who may be interested in a case of constructive engineering of an unusual nature. The matter of foundations, towers, anchorage masonry, and other parts of the bridge will not be treated in this article, as they are only such as are commonly met in engineering practice, and do not belong exclusively to a

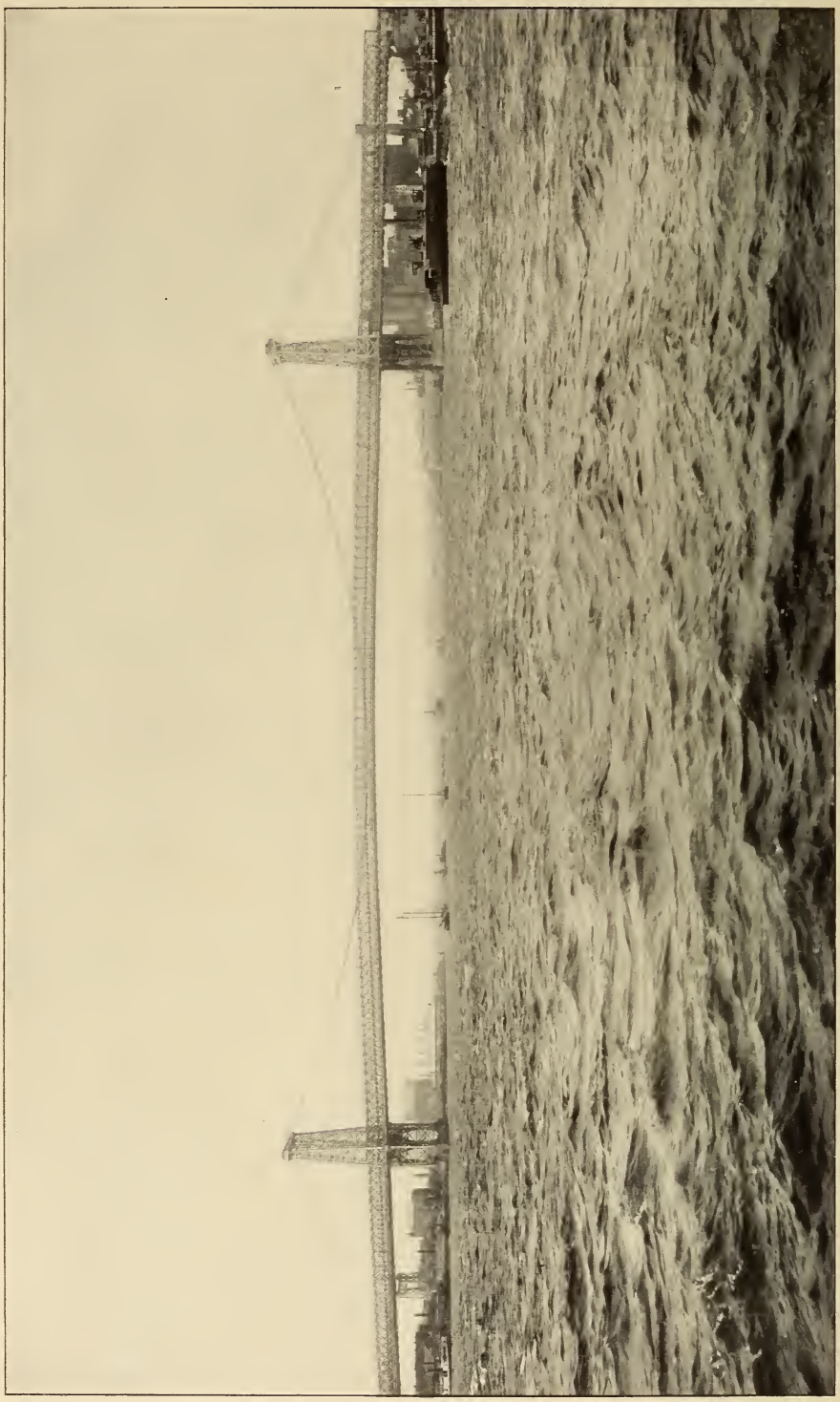

FIG. 3.—THE NEW WILLIAMSBURGH BRIDGE ACROSS THE EAST RIVER, CONNECTING NEW YORK AND BROOKLYN

From a Copyrighted Photograph by George P. Hall & Son, New York

bridge of this type; but the cables of a suspension bridge are the backbone of the structure, and the vital part upon which the bridge itself is dependent. They are also the only parts of the work presenting any unusually difficult problems which require novel methods for their solutions. When it comes to suspending in mid air, 1600 feet between supports, about 5000 tons of steel wire, we have a proposition which every engineer does not encounter, and which only great skill and rare experience can successfully accomplish.

FIG. 4.—THE MAIN SPAN OF THE FOOT BRIDGE SEEN FROM BELOW

In order that the subject of this article may be more fully comprehended, a brief preliminary description of the whole bridge will be given. Fig. 3 is a general view of the completed structure between anchorages, the main features of which are two towers standing at the water's edge, a stiffening truss reaching from tower to tower, a set of four cables passing over the tops of the towers and supporting the stiffening truss, a masonry anchorage on each shore, back of the towers, to which the ends of the cables are attached, and a truss bridge in two spans connecting each tower to the anchorage back of it.

The towers are of steel, and are 335 feet high and 1600 feet apart. Mounted on the top of each are four cast steel saddles upon which the cables rest.

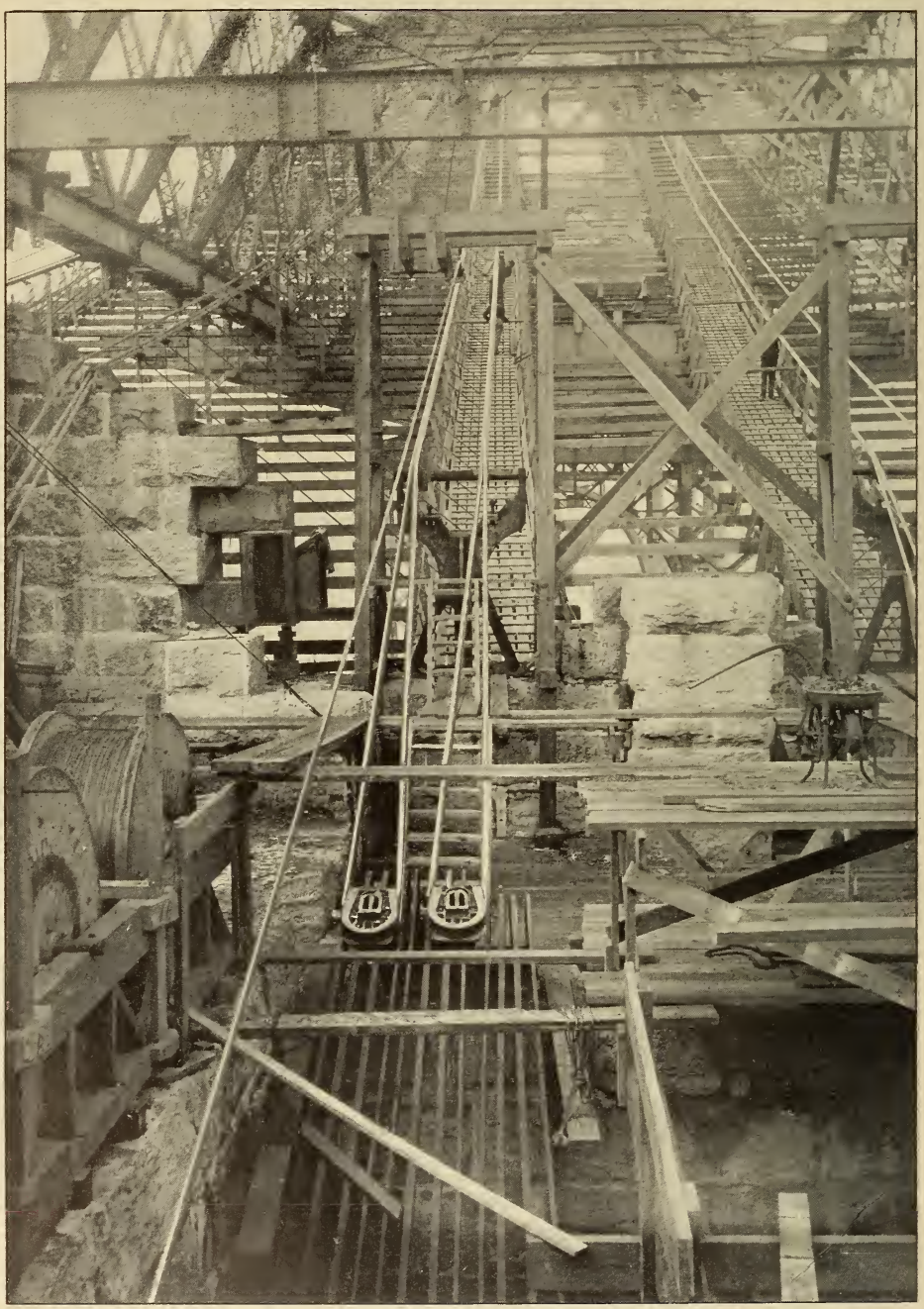

FIG. 5.—FIRST TWO STRANDS IN THEIR TEMPORARY POSITION AFTER ALL WIRES WERE SPUN

FIG. 6.—THE SHOES AROUND WHICH THE ENDS OF THE STRANDS ARE SPUN

The roadway of the bridge passes through the towers at an elevation of about 125 feet. All elevations referred to are measured from an established bench mark, taken at the level of mean high water. The towers are divided at the base, and are supported on two stone foundations resting on bed rock, the deepest about 115 feet below water. The stiffening trusses of the main span are 40 feet deep and 67 feet apart. An overhanging roadway on each side extends 20 feet beyond the trusses. The main span has a camber of about 20 feet, and there is a clear distance between the water and the lowest part of the bridge of 135 feet for a distance of 400 feet at the centre.

The bridge contains two driveways, two footwalks, two bicycle paths, two tracks for elevated railway trains, and four tracks for trolley cars, making in all the most commodious bridge ever built. The main span of the structure is carried by the four cables. Each cable is composed of 7696 steel wires, bunched together in a cylindrical form, measuring about 19 inches in diameter. Each wire is 0.192 inch (about 3-16) in diameter. The contract required that they should have an ultimate tensile strength of no less than 200,000 pounds per square inch. A sample from every piece of wire used in these cables was subjected to test, and the average strength was shown to be considerably over that required by the specifications.

The wires are laid parallel to one another throughout the length of the whole cable, and are held together by substantial steel bands 20 feet apart. These also serve as saddles for the suspenders by means of which the stiffening truss is hung to the cables. The ends of the cables are attached to the ends of chains of eye-bars in a manner which will be described later. The other end of the anchor chain is imbedded in the masonry of the anchorage. This anchorage is 600 feet back of the tower, and is about 150 feet square and 100 feet above ground. It is built of stone and concrete, and is deep enough to secure a good foundation and be safe against any danger of sliding forward under the great strain of the cables pulling upon it.

That part of the bridge between the tower and the anchorage is supported independently of the cables by means of a truss construction, one end resting on the tower and the other upon the anchorage, with an intermediate support half way between. Back of each anchorage the bridge is continued on columns until it meets the ground. These approaches are 2500 feet long on the New York side, and 1900 feet long on the Brooklyn side, and form, with the rest of the structure, a bridge 7200 feet long.

In the design of a structure of this kind one of the first things to consider is the weight which the cables will be called upon to support. Let it be supposed that the general size and capacity of the bridge has been decided upon. That will give the live load for the main span, from which can be computed the weight of the stiffening truss. In this particular case only the main span is supported by the cables, so that we get a dead load of 15,000 pounds per lineal foot, and a live load of 5700 pounds per lineal foot.

We now know the span of the cable, its deflection (difference in elevation between its supports and lowest part), and the load which it is expected to carry. By means of the formulæ of the catenary and the parabola, it is possible to find the tension in the cable due to its own weight, and to that of the suspended stiffening truss with its corresponding live load. By the use of the same formulæ, it is also possible to determine the downward pressure upon the towers and the horizontal pull on the anchorages in order to proportion their size and strength. Where the cables pass over the towers, they rest in saddles of cast steel, as already mentioned, which are mounted on rollers and arranged to roll about 3 feet in the direction of the axis of the cable. The object of this is to permit the cables to move over the tower during changes in tension, due either to temperature changes or differences in loading, and thus relieve the towers of any side strains.

The bridge was designed by, and built under the direction of, L. L. Buck and a corps of engineers representing the city of New York. The specifications included in the contract for the cables described the position at a certain temperature which the cables were to occupy after being completed, and with the suspenders attached to them, but with no load or superstructure. It, therefore, devolved upon the contractor to devise means of suspending the cables so that they should exactly occupy the required position. It was necessary to know where to set the saddles on the towers at the beginning of wire spinning, so that they would roll into the correct position and balance the horizontal forces on the tower when the weight of the main span superstructure became suspended to the cables. The contractor was made responsible for the correctness of this work. It required him to devote much time on intricate and difficult calculations in order to determine the exact place to locate the saddles.

Let us now consider the operation of building such cables as those here considered, and let us, therefore, assume that the towers and anchorages are complete. The first thing to do is to get some suspended connection between the two towers. In other bridges various methods of accomplishing this have been tried. The simplest and most practical way would be to take a light line across in a boat, and then raise each end to the top of its tower. Where the river is not navigable, as at the Niagara Rapids, for instance, a line may be shot over by a cannon, in the same way that lifesavers shoot a line out to a stranded ship; or it may be carried over by a kite. In one case the ambitious engineer swam across the stream, taking the line with him.

In the case of the Williamsburgh Bridge the operation was carried out in a manner entirely different. In the first place it was decided to erect a temporary suspension bridge from which the cables of the main bridge while under construction could be ac-

cessible throughout their length from anchorage to anchorage. This meant a separate foot bridge directly below and about 3 feet from the imaginary line of each of the proposed cables.

Fig. 2 is a general view of this foot bridge, showing upper and lower decks in main span. It was more than an ordinary footwalk from tower to tower. In the main or river span it was a double-decked bridge, and consisted of eight continuous footways, four above and four below. The four upper footwalks were about 3 feet below the line to be occupied by the strands of the cable during the time of spinning. The four lower walks were just below the line to be occupied by the cable when the strands had been placed in their permanent positions.

Fig. 1 shows the span of the foot bridge as seen from the top of one of the towers. The travelling sheave is shown decorated with the American flag while stringing the last wire for the four cables.

These different footwalks were connected by cross bridges at numerous points, so that an easy communication was afforded from all parts of the structure. These cross bridges also served to stiffen the bridge laterally in conjunction with a series of storm cables, suspended below the footwalks in the form of inverted parabolæ, and guys running to the towers. Fig. 4 is a view of the main span from below, showing the storm cables and guys. The two land spans were placed directly below the line of the cables, and had only a single deck of four walks.

The whole structure was supported by sixteen wire ropes, assembled into four groups of three ropes each, with a single rope suspended above each group. These ropes were stretched from anchorage to anchorage, and passed over the tops of the towers in saddles especially provided for them. The three ropes composing a cable were clamped with iron bands every 5 feet, so as to keep the three together throughout their entire length. They were $2\frac{1}{4}$ inches in diameter, and were made of seven strands of galvanised steel wires, twisted together. The ultimate tensile strength of each was 208 tons, and the weight 9 pounds per foot. Each rope was made long enough to extend the entire distance from anchorage to anchorage, about 3020 feet.

The framework of the bridge consisted of yellow pine and spruce timbers placed upon and suspended to these wire rope cables. It was necessary to compute the position of these cables and adjust them with a great degree of accuracy, so that the foot bridge would hang in the proper place and fulfill the purpose for which it was intended.

With this general idea of the foot bridge structure, let us proceed to examine into the method of its erection. Instead of a preliminary light rope to connect the two towers, the foot bridge cables themselves were suspended at once. The wire ropes forming the cables were 3020 feet long, as already mentioned, and were brought to the site on large reels, each with the rope upon it weighing 14 tons. They were conveyed to the foot of the New York tower by a large wrecking tug having a powerful derrick on its deck. This lifted the reels and placed them upon the deck of a large float moored there, which had been previously used for the transfer of freight cars around the harbour. Three reels at a time were mounted on this float, and set up on shafts and bearings, so that they could be revolved and the ropes unwound from them.

There was also a hoisting engine on the float, from which a line was carried up to the top of the tower and passed through a pulley and down again to the deck of the float. There it was clamped to one of the $2\frac{1}{4}$-inch ropes about 60 feet from its end, which was then unwound and drawn up to the top of the tower. The loose end was passed over the tower towards the land, and rested in sheaves mounted on the top of the saddles. By the assistance of another hoisting engine near the anchorage, the rope was pulled back to the anchorage and at-

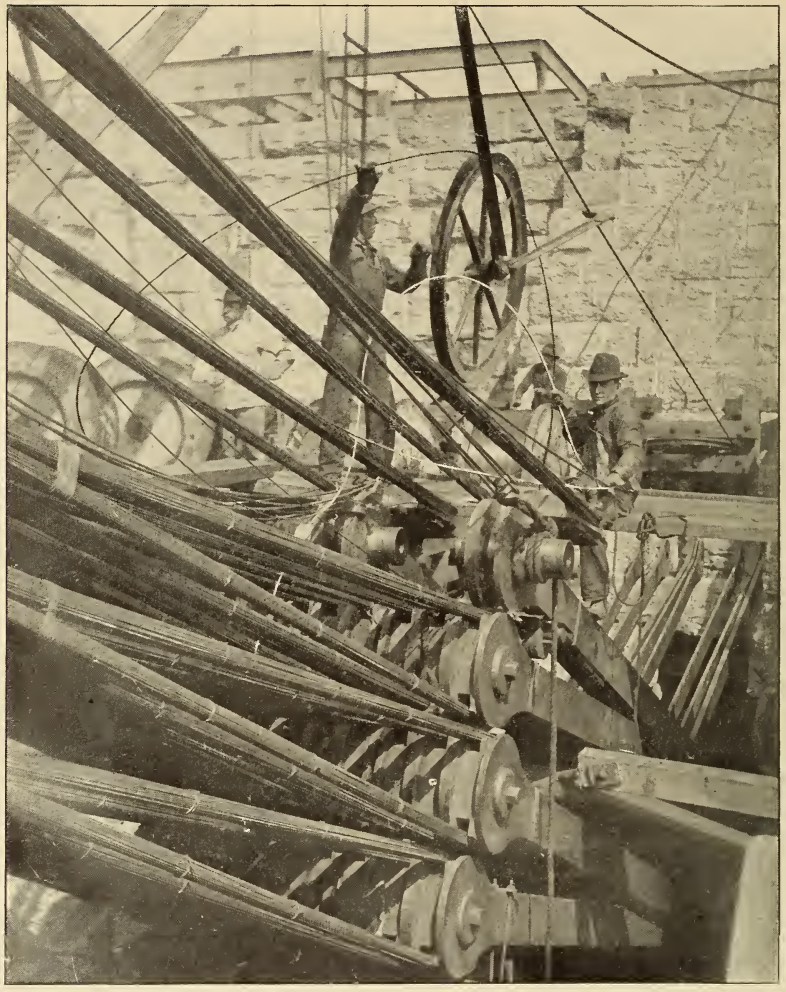

FIG 7.—THE TRAVELLING SHEAVE WITH WIRE BEING PLACED UPON IT

tached to its permanent fastening there.

This operation was repeated until the three ropes forming the first cable were all over the tower and made fast to their anchorages. Where the ropes ran down to the foot of the tower, they were temporarily lashed to it. The float was then towed across stream, allowing the reels to pay off the ropes, which sank and lay upon the bed of the river. The reels were fitted with brakes to prevent them from unwinding too fast and entangling the ropes.

Three powerful tugboats were used to tow the float across and keep it on a straight course. The operation was performed at slack tide, so that it could be more easily managed and other craft could be controlled and kept out of the way. When the float reached the foot of the Brooklyn tower there still remained about 400 feet of rope on each reel. This was unwound from one reel at a time and strung out on the deck of the float, until the end of the rope was reached, which was then hauled up and passed over the top of the tower. A three-part tackle, operated by a powerful hoisting engine on the Brooklyn anchorage, was then attached to the rope, and all was in

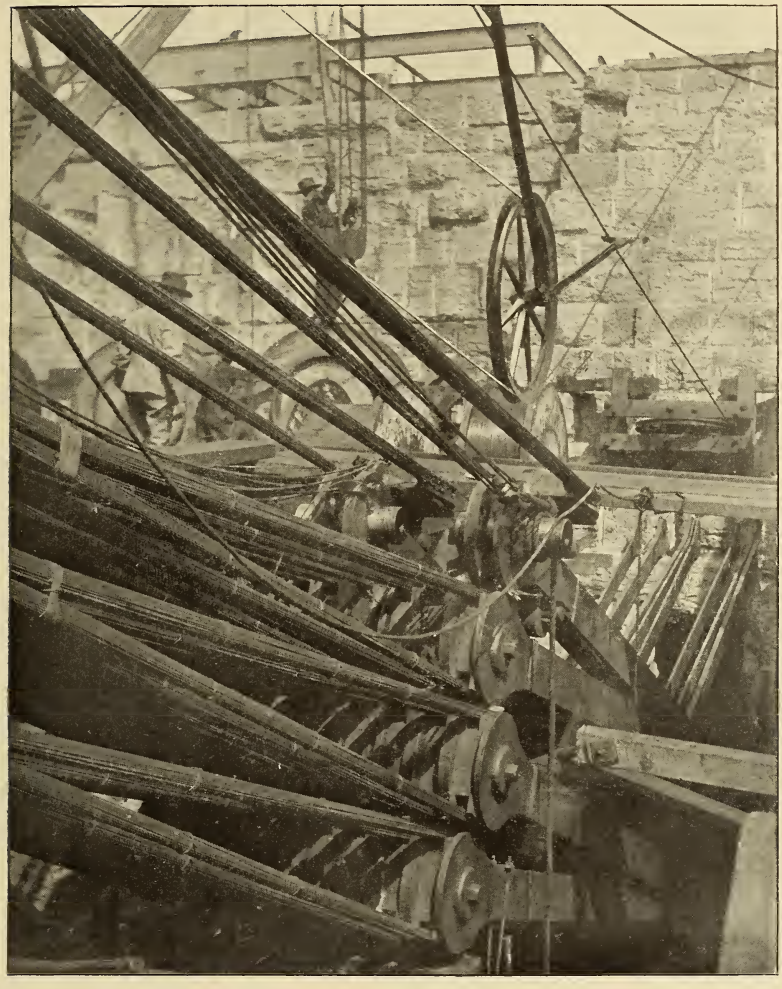

FIG. 8.—THE TRAVELLING SHEAVE AT THE END OF ITS JOURNEY

readiness for the final pull, which was to raise the rope from the bed of the river and leave it suspended from tower to tower.

Before this was attempted the river was guarded up and down stream by government patrol boats to prevent passing craft from getting into danger and interfering with the operation. At a given signal the hoisting engine on the Brooklyn anchorage began to pull on the tackle. Slowly the mighty cable slipped over the top of the Brooklyn tower and gradually left its resting place at the bottom of the river, finally swinging free 150 feet in air and supplying the first suspended connection between the two parts of the bridge. This delicate, yet ponderous, operation once successfully accomplished, permitted those concerned in its execution to breathe a sigh of relief, giving them confidence in their ability to repeat the same till all twelve ropes should be similarly suspended.

Each rope was adjusted to its proper position by sliding it over the tower till it hung at the correct deflection for each span. This was measured for the main span by a level set up in the tower; for the land spans, a transit was

FIG. 9.—AT THE TOP OF ONE OF THE TOWERS. ONE OF THE SADDLES IS HERE SHOWN, WITH A STRAND BEING SPUN.

set up at a known point and at a certain angle, the line of which was tangent to the curve.

The timber work of the foot bridge was framed on the ground below and hoisted to the tops of the towers. It was then carried out on both sides of the towers and attached to the cables. The men who did this worked from travellers which ran by means of sheaves over the cables, and just ahead of the work of assembling the frame. Two of these travellers from each tower started down on the main span working towards the centre, and two travellers from each tower on the land spans were working at the same time towards the anchorages. When the main span travellers met at the centre of the bridge they were taken apart and carried back to the towers.*

With the foot bridge finished, work could proceed on the actual cable spinning. First, however, it was necessary to install some machinery to haul the wires from one end of the bridge to the other. This, in part, consisted of two endless travelling ropes, $\frac{3}{4}$ inch in diameter, and made of the strongest steel wire used for such purposes. These wire ropes were supported at various points along the foot bridge on iron sheaves, and were driven by engines on the New York anchorage.

* A full description of the foot bridge and its construction was given in a paper by the author, entitled "The Foot Bridge for Building the Cables of the New East River Bridge," presented before the American Society of Civil Engineers, and published in 1902 in Vol. XLIX. of their transactions.

They ran from anchorage to anchorage just above and in the plane of each cable.

The first travelling rope crossed the bridge over the first cable and returned over the second cable. The second travelling rope crossed the bridge over the third cable and returned over the fourth cable. The motion of the travelling ropes could be stopped or started at will, and reversed so as to run in either direction. A system of electric bells was installed, with push-buttons at numerous points along the foot bridge and on the towers and anchorages. By means of these the men who ran the machinery for controlling the travelling ropes could be communicated with instantly. There was also installed a system of telephones connecting towers, anchorages, and main span, which greatly facilitated the execution of the work of cable-spinning.

To each travelling rope there were attached two travelling sheaves, so situated that when one of them was at one anchorage the other was at the opposite anchorage. As the travelling rope was put in motion, it conveyed one travelling sheave across the river in one direction and brought the other across in the opposite direction, each passing just above the line of the different cables.

Each travelling sheave was a stout wooden wheel with a deep flange of sheet iron forming a groove about its circumference. It was suspended to the travelling rope by means of a strong frame of angle iron clamped to it by goose-necks, and so arranged that it would not interfere with that part of the rope passing over its supporting sheaves. Figs. 1, 7, and 8

FIG. 10.—TYING IN A NEW WIRE AT THE CENTRE OF THE MAIN SPAN

FIG. 11.—"LETTING-OFF" APPARATUS FOR ADJUSTING A STRAND TO ITS PERMANENT POSITION

show the travelling sheave in use. The purpose of the travelling sheave was to convey the bight of a single wire across from one anchorage to the other. To facilitate construction, and for convenience in connecting to the anchor chain, each cable was divided into 37 different strands. Each strand consisted of 208 wires, or more correctly, a single wire spun back and forth over itself 208 times, just as you find a skein of yarn before it is wound into a ball.

Fig. 5 shows the first two strands of one of the cables after all the wires have been spun. This skein of wire is 3 inches in diameter and 3000 feet long. Each end is spun around a cast-steel shoe, so called because its shape resembles that of a horse shoe. Fig. 6 is a closer view of the shoes with the strand only partially spun. This long wire is composed of a number of shorter pieces spliced together, the ends being joined after it is all spun. Each separate piece of wire is 4000 feet long. These pieces are joined by a sleeve-nut with a right and left-hand thread, and are brought to the site already spliced and wound on reels about 7 feet in diameter.

Each reel contains about four tons of wire. This means a piece of wire 15 miles long. These reels were hoisted to the top of the two anchorages and mounted on shafts at the side of each anchor chain, so that the wire could be unwound from them and drawn across the foot bridge. Each reel was supplied with a brake, so that it would pay off the wire only as fast as it was needed.

Before the operation of spinning the cables could be commenced, it was necessary to establish guide wires. These consisted of single wires of the same size and quality as the wire of the cable. Their use was that of a measure or guide for the correct length and position of each strand as it was made. Two strands of a cable were being made at the same time; hence there were required two guide wires for each cable, or eight in all. On account of the arrangement of the shoes at the end of the anchor chain,

the land span of each strand was of a different length. This required a guide wire of different length for each strand. These various lengths were calculated, and their differences were added to or subtracted from the length of the first guide wire by means of a turnbuckle attached to each end. In calculating and adjusting a guide wire it was supposed to occupy the position of the centre of the strand to which it corresponded.

The adjustment of the guide wire for the first two strands of each cable was a very delicate and important operation. Its preparation required a mass of intricate calculation, involving the formulæ of the catenary and the parabola. It was known at what elevation the finished bridge should hang at a certain temperature. From that it was necessary to compute the position of the cables unloaded, and at various temperatures. It is not one of the objects of this article to attempt to explain the mathematical process of this work, but it was one of great intricacy, requiring the most exact and painstaking computations, and occupying the time of two engineers for many weeks. The facts sought were these:—

1.—The angle at which to incline the telescope of a transit set up at a known point in the plane of and below each land span of the strand, so that the line of sight would be tangent to the strand at its lowest point while hanging in its correct position.

2.—The exact elevation at which to set a level in one of the towers, so that its line of sight would be tangent to

FIG. 12.—LOWERING A STRAND INTO A SADDLE ON ONE OF THE TOWERS

the strand at its lowest point while hanging in its correct position.

These facts had to be determined for all temperatures which were liable to exist at the time of making the adjustment. With this information at hand, it was possible to adjust the two guide wires for the first two strands of each cable. The operation was begun on one land span, and after that was correctly suspended, a mark was made on the saddle in which it rested on top of the tower, and a corresponding mark on the wire at that point, so that it could always be restored to the same position after having been removed.

The main span was next hung at its correct position and the wire and saddle marked on the other tower. The adjustment of the remaining land span completed the adjustment of the guide wire, when its end was cut off and a turnbuckle fixed the exact length. For all strands after the first two in each cable the length of the main span remained the same, so that the length of the guide wire in the main span was fixed once for all. In the land spans, however, each strand was of different length, and these differences were calculated, and the lengths of the guide wires were altered accordingly by means of the turnbuckles before setting them for use on a new strand.

The shoe around which the end of the strand was looped contained a slotted hole for a 7-inch pin. (See Fig. 6.) This slotted pin hole permitted the shoe to be moved on the pin $3\frac{1}{2}$ inches in either direction, the space back of the pin to be filled with a packing of steel plates, so that the strand, after being made, was yet adjustable in length to the extent of 7 inches at each end. Before beginning to spin wires the shoes at each end for each of the two strands of a cable were supported and made fast a distance of about 2 feet back of their final position on a steel casting called a "leg." This contained a table upon which the shoe rested, and a lug which passed through the shoe in the place to be afterwards occupied by the pin. The leg was secured to the end of the anchor chain, so as to resist the pull of the strand during construction.

The saddles on top of the towers were steel castings, 19 feet long, mounted on rollers. They were rolled toward the shore 3 feet off the centre, preparatory to spinning the cables, this being the calculated distance necessary to balance the horizontal forces in the cable with no weight of the main span stiffening truss upon them. On top of each saddle and on each side of the groove for the finished cable there were mounted a row of sheaves. These were to temporarily support the strand while it was being spun, as shown in Fig. 9.

The equipment was now complete for the operation of spinning wires. Men were stationed at each anchorage, on each tower, and about 200 feet apart all along the footwalks. The travelling rope was moved so that the travelling sheaves were brought one to each anchorage. Assuming the observer to be on the Brooklyn anchorage, the end of a wire from one of the reels was passed over and around the travelling sheave. This end was then made fast to the shoe. The travelling rope was then set in motion, and the travelling sheave moved forward across the bridge, carrying with it the bight of wire and unwinding it from the reel as it went.

Fig. 7 shows the wire being placed around the travelling sheave preparatory to its trip across the river. Fig. 8 is a view of the travelling sheave just after it has arrived from the opposite side with the wire which it has drawn across still around it. The travelling sheave in motion left two wires in its wake. The one from the bottom groove of the wheel was a standing wire which lay upon the footwalk, and the one in the top groove of the wheel was a running wire, moving across the bridge at a speed of twice that of the travelling rope.

To avoid friction, this running wire was supported on rollers on top of the towers and at various points along the foot bridge. After the travelling

sheave had passed over the Brooklyn tower, the standing wire was placed in the sheaves on the saddles. Fig. 9 shows the travelling sheave just after having passed the tower. The standing wire is being placed into the sheaves at the side of the saddle, and the running wire is about to bear on the long wooden roller, by means of which it will be supported as it is drawn across. The guide wire had previously been placed in the sheaves, and the standing wire could now be drawn up or let down by the men on the tower by means of a light set of block and tackle and a pair of wire-pullers until it hung exactly parallel to the guide wire. This fact was determined by men along the land span of the foot bridge, who signalled to the men on the tower, and these, in turn, lowered or raised the wire until it was exactly correct. It was then securely clamped to the guide wire at the tower and bound to it with twine at points about 50 feet apart all along the foot-walk.

While this was being done the travelling sheave was approaching the opposite tower on the Manhattan side. As soon as it had passed there, the standing wire of the main span could be adjusted, not, however, until the man on the first tower had signalled to the man at the centre of the main span that the adjustment of the first land span was finished. The men on the New York tower then pulled in or let out the wire according to the signals of the man at the centre of the span, who was careful to see that the wire hung exactly parallel to and at the same deflection as the guide wire. When this was accomplished, the men on the New York tower signalled to the man at the centre of the New York land span.

We will assume that the travelling sheave had already reached the New York anchorage and had been stopped there. The running wire now ceased its motion across the bridge, and the bight of wire was removed from the wheel and placed around the shoe. The men on the Manhattan anchorage could now adjust the standing wire, clamp it at the anchorage, and bind it to the guide wire at numerous points along the foot bridge. The running wire, now still, was simply a continuation of the standing wire after it had been passed around the shoe. The adjustment of this was now taken in hand,—first on the New York land span, then on the main span, and lastly on the Brooklyn land span. This done, there was one continuous wire from one anchorage to the other and back again. Fig. 10 shows a man tying in a wire with the rest of the strand after it had been adjusted. In the background is the man at the centre of the main span signalling to the men at the tower to go ahead.

While the running wire was being adjusted from the New York side back to the Brooklyn side, the travelling rope was being run in the opposite direction to its first motion, and the travelling sheave was pulling the bight of a new wire from the New York anchorage to the Brooklyn anchorage. This wire was intended, however, for the other strand of the cable, and it was adjusted in the same manner as just described for the other wire. The necessity of two guide wires is now apparent. When the travelling sheave had reached the Brooklyn anchorage, it was once more stopped and relieved of the wire it had just drawn across. It was then ready to take up the bight of the wire of the first strand and make its second trip from Brooklyn to Manhattan. This operation was repeated until there were six or eight wires laid and adjusted in each strand. The guide wires were now separated from the other wires and laid aside until needed for the beginning of the next pair of strands. When the subsequent wires were laid, they were adjusted by those already in place. When 208 wires were laid in each strand, the wire was cut at the point where it met the first end. The two ends were then spliced together at the correct tension, and the strand was complete so far as wire spinning was concerned.

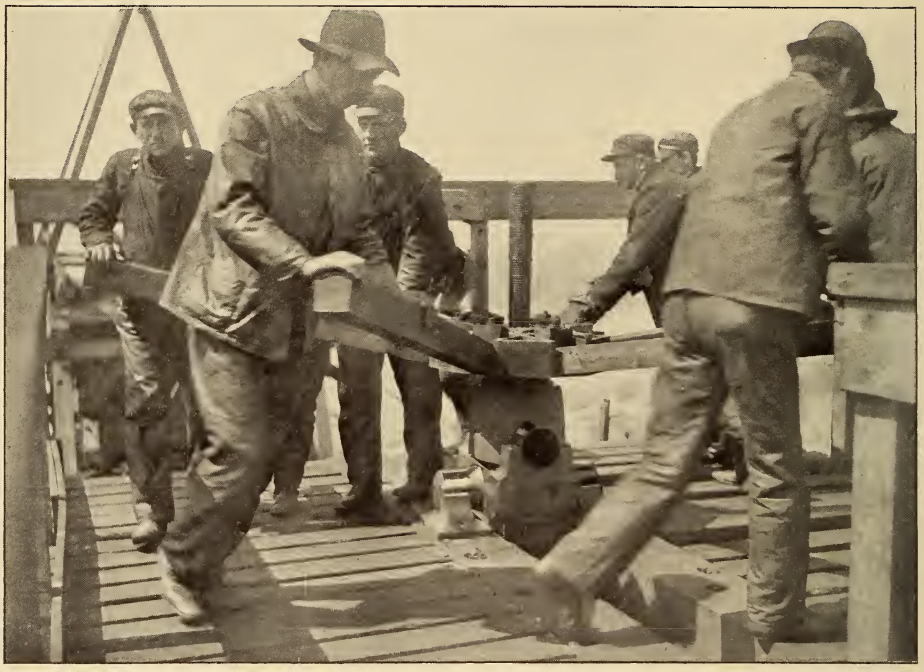

FIG. 13.—WORKING THE SCREW FOR LOWERING A CABLE STRAND INTO ONE OF THE TOWER SADDLES

It must be remembered that there were two travelling sheaves on each travelling rope, so that it was possible to carry on the work of wire spinning for two cables simultaneously. The other two cables were equipped with another travelling rope, so that the work was conducted on all four cables at the same time, and on two strands in each cable. This was twice as fast as it had ever before been done. In the case of the old Brooklyn Bridge, the wire was fed from one anchorage only, so that the travelling sheave made the return trip empty.

With all the wires laid in a strand, the next step was to squeeze it into a cylindrical form and serve it from one end to the other. This was done by wrapping a few turns of soft wire around the strand at intervals of about 15 feet. This was intended to keep each strand intact until all the strands were complete, and was only a temporary wrapping, except at the part of the strand within the anchorage. There the wrappings were permanent and were placed about 4 feet apart.

The fact of holding the shoe back of its final position, and of supporting the strand on the tower above its final position during the operation of wire spinning, had the effect of causing the strand to hang with a less deflection than after it was adjusted. This difference in elevation at the centre of the main span amounted to about 14 feet; hence is seen the necessity of having a foot bridge of two decks, one from which to reach the strand while making, and one from which to reach the strands after being lowered into their permanent positions.

The final adjustment of the strand consisted of two operations. One was to lift the strand from the sheaves on top of the saddle and lower it into its final resting place in the saddle. The other was to lift the shoe from the leg and slack off the strand until the shoe came to its proper place between the eye-bars at the end of the anchor chain. This letting-off was done by means of a powerful turnbuckle with

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a 4-inch screw, worked with a ratchet. Fig. 11 shows this apparatus after it had let one strand forward to its correct position between the eye-bars. After this shoe was secured on the pin, the shoe of the other finished strand was taken hold of and adjusted similarly.

The lifting of the strand on top of the tower was performed by means of another screw, the nut of which was mounted on roller bearings and a double trunion block on top of a timber framework over the saddles. In Fig. 12 is seen a strand being lifted from the sheaves and lowered into the saddle. A frame of two channel irons is suspended to the screw, and the strand is made fast to the links of various length by means of wires which can be cut and pulled out after the strand comes to its final bearing in the saddle.

Fig. 13 shows the screw and trunion block above, with the men furnishing the power for lifting the strand. The adjustment of the strand to its exact position was made like that for the guide wires, with transit and level.

It has never been possible in practice to make a strand to the exact length desired. It is a very difficult thing to measure on the ground two lines of great length, and have them exactly the same. Much more so is it to measure two wires suspended in mid-air, exposed to winds and varying temperatures, and where the "personal exponent" is one of high power. The variation in the lengths of these strands was from 1 to 4 inches, averaging about 1 inch in 1200 feet of length. This was taken care of by putting more or less packing in the shoe back of the pin.

A pair of strands being now complete and adjusted to their final positions, they were out of the way, so that work could be begun on the spinning of a new pair. In this manner

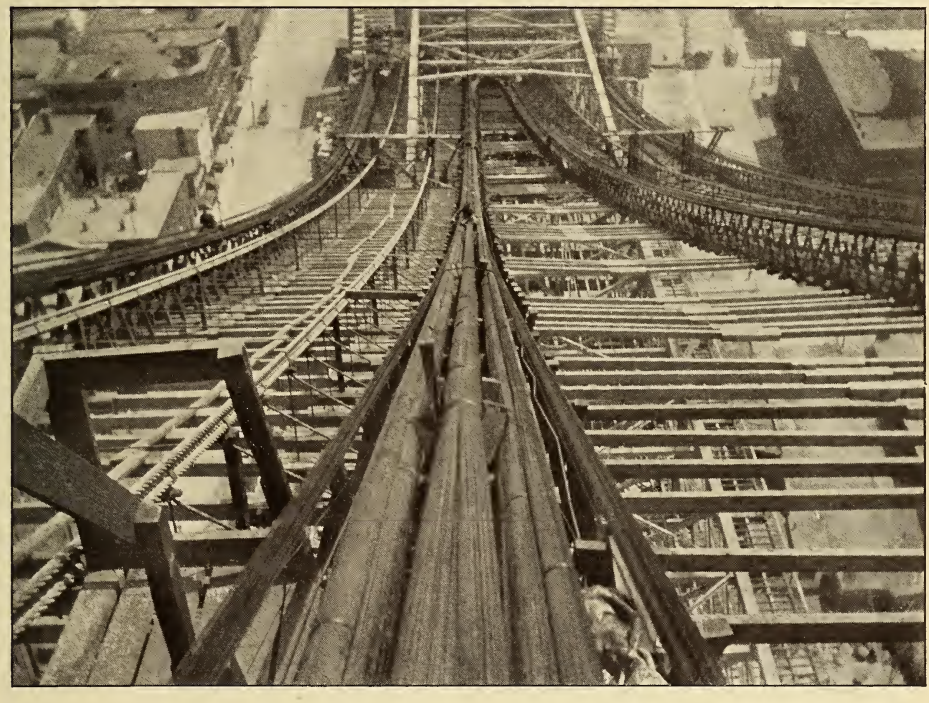


FIG. 14.—THE CORE OF THE CABLE, SQUEEZED AND WRAPPED

37 strands were made and each was fitted to its proper place in a hexagonally shaped group. When the seven strands forming the centre of the cable were finished, the strand wrappings were removed and the whole seven were squeezed into one cylindrical mass and bound with wire to form the core of the cable, and to make the final squeezing of the whole cable less difficult. Fig. 14 shows this centre of seven strands wedged apart from the other strands, and served about every 5 feet with a fine wire wrapping.

Fig. 15 shows the strands all finished with their permanent attachment to the anchor chain. About 100 feet apart can be seen temporary bands for keeping the wires together until the more powerful bands for doing the final squeezing could be applied. The upper deck of the main span of the foot bridge was now no longer needed. It was, therefore, taken down, and the whole of the lower deck was floored over, so that the cables could be reached with ease. The serving had already been removed from the individual strands before applying the preliminary squeezers, so that the final squeezing was now done by means of powerful cast steel bands used in two pairs placed opposite to each other.

Fig. 16 shows the operation of squeezing a cable. Large wooden mallets were used to pound the wires and assist in bringing them into a compact mass. This squeezing was done every 4 feet, and when the cable was brought down to the smallest possible diameter, a wrapping of 12 turns of heavy wire was applied. Fig. 17

FIG. 15.—THE FINISHED STRANDS, WITH THEIR ATTACHMENTS TO THE ANCHOR CHAINS

FIG. 16.—SQUEEZING THE CABLE

shows this wrapping next to the squeezer before the latter was removed.

Fig. 18 shows a main span cable band in place. Two pairs of squeezers were placed at each side of this band while it was being put in place.

To protect the wires of the cable against rust, they were coated, before leaving the mill, with a heavy oil, mixed with a finely ground graphite. This compound was used also to fill the interstices between the wires after they were assembled in the cable. The cable was finally wrapped between cable bands with cotton duck saturated with another waterproof compound. The whole was then covered with a shield of sheet steel fitted between the cable bands in halves, and strapped together so as to shed water.

The suspenders were made of 7-strand steel wire ropes, $1\frac{3}{4}$ inches in diameter. The ends of each rope were fitted with screw sockets, one with a right-hand thread and the other with a left-hand thread, so that they could be joined with a sleeve nut. This rope

FIG. 17.—APPLYING THE SERVING

FIG. 18.—A MAIN SPAN CABLE BAND

passed over one cable down to a floor beam of the stiffening truss and up again over another cable, the two ends being returned to meet.

The four cables were cradled in two pairs in the main span; that is to say, the two cables on the southerly side were drawn together to within 4 feet of each other at the centre of the span, while they were 22 feet apart at the towers. The two northerly cables were cradled in the same manner. The object of this was to resist any side motion due to wind pressure or other causes. After the cables and suspenders were fully completed, all parts received two coats of white paint to further protect them against oxidation.

Just before the work was completed and while the weather-proof duck covering was being applied to the cables, a fire occurred on the New York tower. The temporary woodwork there burned rapidly and heated the footbridge cables to such an extent that they were weakened and two of them broke, entirely wrecking the foot bridge. The main cables were scarcely injured. On only one were any repairs needed. A few of the outside wires had become heated to such an extent that they were annealed and lost their strength. These were cut out and new wires spliced in and a few extra ones added. The wrecked foot bridge was removed, and another, simpler one, was suspended to the main cables where needed to complete the work of covering them.

Although this work is considered a particularly hazardous sort of occupation, the contractors were fortunate in having very few accidents. One man lost his life by falling from the foot bridge into the river, clearly through his own negligence, and not while actively engaged in his work. Another man was severely injured by a heavy reel rolling upon him, but he has since entirely recovered. These were the only two accidents to men engaged on this contract, while a number of lives were sacrificed on all other parts of the work. Twenty in all were lost. But in construction work of such proportions, human lives are usually a part of the price we pay. The bridge itself will stand as a monument to their memories, and, partially raised by their own hands, no other mark could more fittingly remind us of the daring and skill of those who helped in its creation.

STEAM ENGINEERING IN PAPER MILLS

By E. S. Farwell

IN many industries steam engineering plays a much more important part than that simply of furnishing power. In such instances the best results can be secured only by a careful study of the conditions peculiar to that industry. In the manufacture of paper much steam is used, and it is here that some of the most interesting problems are to be found. An examination of many mills, however, shows a lamentable lack of appreciation of what might be accomplished in this line.

The item of fuel has a prominent place on the cost sheet of a paper mill. It is not sufficient to buy the cheapest fuel that can be secured, nor even that which will give the greatest amount of steam for a certain quantity at a certain price.

The boilers may be giving fairly good results, the valves of the engine may be very well adjusted and not leaking enough steam to pay the wages of a first-class engineer, but beyond that there is an opportunity for wasting two or three times over the wages of a capable man.

The earlier processes in the manufacture of paper vary with the material or "stock" of which the paper is made. In all of them more or less of the material is cooked with steam. After screening, the stock goes to the beaters, where it is frequently kept at steaming temperature. As it approaches the machine, it is again heated to make it flow better. The dryers must be kept hot. Then, on some papers, a steam jet is used at the calenders to get a certain finish.

In the manufacture of sulphite, the chips are cooked eight or nine hours by direct steam at a temperature corresponding to 70 pounds pressure. After supplying sufficient heat to bring the contents of the digester to this temperature, which may take an hour, the remainder of the time it is merely a question of replacing the heat lost by radiation. While the effectiveness of the acid is very rapidly reduced by the dilution from the condensed steam and water carried over with the steam, no attempt is made to reduce this radiation.

If it is impracticable to cover the digesters with a non-conductor, the room can at least be kept hot from some other source than the radiation from the digester surface, or a hot-air jacket could be used. By carefully taking the temperature of the shell and that of the surrounding air, the amount of heat radiated can easily be computed and checked back to the coal pile. Again, as a means of reducing the dilution, high pressures and superheated steam may be used, care being taken not to introduce it in such a way as to char the wood.

The process for the cooking of soda fibre is very similar to that for sulphite. But while here the dilution of the liquor is not so detrimental, the digesters are usually covered with a non-conductor. The same is true of rag boilers.

The amount of steam that should be required to dry paper can easily be calculated after making several more or less uncertain assumptions. It seems to be uncertain whether all the water that is driven off from the paper when drying is actually evaporated into steam at 212 degrees. Some of it may be carried off by the air in a hygroscopic state. As the steam pressure inside of the dryers is generally

about 5 pounds, the temperature will be above 212 degrees, and it may be fair to assume that the water passing off from the paper is at first evaporated, although it may condense very soon after leaving the paper.

Other factors which enter into the problem are the amount of moisture in the paper as it comes from the last press, the steam pressure carried in the dryers, the ratio of drying surface to the speed of paper, and to the wasteful radiating surface; that is, surface not in contact with the paper but radiating heat to the air.

As the paper leaves the presses for the dryers it contains from 65 to 75 per cent. of water. A small percentage of this water remains in the paper when it reaches the reel, so that on the average it is fair to assume that for every pound of paper made, 2 pounds of water must be evaporated. The temperature of the water as it comes from the presses may be assumed to be about 65 or 70 degrees. Then to heat the water from 65 degrees to 212 degrees and evaporate it into steam will require 1113 British thermal units per pound of water.

In modern machines the steam pressure in the dryers is carried at from 1 to 6 pounds. The water as it leaves the dryers will have a temperature of about 210 degrees. One pound of steam at 5 pounds pressure contains 1183 heat units, of which it will give up $1183 - 210 = 973$ heat units. If, then, all of this heat went into the water of the paper, the amount of steam required per pound of paper would be

$$\frac{2 \times 1113}{973} = 2.29 \text{ pounds.}$$

This makes no allowance for radiation from the machine nor for the heat required to raise the temperature of the paper itself from 65 degrees to 212 degrees, nor for any other leakage or wastes. If it is possible in the presses to reduce the amount of moisture in the paper 6 per cent., the amount of steam required would be 1.72 pounds instead of 2.29 pounds. This clearly indicates one point to be carefully watched.

Increasing the pressure carried in the dryers makes more heat available from each pound of steam if the temperature of the return water is kept below 212 degrees. In addition to that, the temperature in the dryers being higher, each square foot of surface will transmit more heat, drying the paper faster or with a fewer number of dryers. There is an objection, however, to carrying a higher pressure in the dryers, which in nearly every case offsets the advantage just noted. If steam at 10 pounds pressure or more is carried in the dryers, it will blow through the syphon pipes and be carried back to the hot well without becoming condensed and giving up its latent heat.

This loss may be excessive. Many machines are driven far beyond their economical speed, requiring high steam pressures and consequent losses. A reduction in speed of 10 or 12 per cent. will reduce the pressure required and save from 5 to 10 per cent. of the fuel consumed per pound of paper. Increasing the number of dryers on the machine will produce the same results without curtailing the output.

In a machine having a large number of dryers, the tendency is for the steam to blow through some of the dryers near the calender end, and equalise the pressure on the steam and return headers. If the dryers depend on syphons to empty them, the result will be that many of the dryers will not discharge their water until half full, resulting in streaky and irregular drying.

Various devices have been installed to remedy this trouble, showing large returns on the investment. In order that there may be a sufficiently rapid transfer of heat to satisfactorily dry the paper, there must be a temperature in the dryers above 212 degrees. The fewer the number of dryers, the higher must be that temperature; and conversely, the greater the number, the lower the temperature. However,

in every machine designed to run at a given speed, there is a certain number of dryers, beyond which it is not economical to go, as any further reduction in temperature of steam will prevent the necessary transfer of heat. The result will be excessive radiation losses without proportionate gain.

Tests on machines using live steam show a consumption of about 2.80 or 2.90 pounds, which represents about 25 per cent. in radiation and other unaccounted for losses. In the same machines, when using exhaust steam, the steam consumption is from 15 to 20 per cent. greater, or 3.3 pounds per pound of paper. This small additional steam consumption is in reality the cost of the power to drive the machine, and it is an exceptional case where that cost is not less than the cost of any other power.

Here, again, superheated steam may sometimes be used to advantage. It will reduce the heat losses in the engines and consequent steam consumption, but will probably not reduce the amount of heat available for drying.

The presence of cylinder oil in the exhaust may coat the interior of the dryers to such an extent as to impede the necessary rapidity of transfer of heat. The best oil separator obtainable should be installed in the exhaust near the engine.

All consideration of fuel consumption has so far been purposely omitted. The amount of steam which can be produced per pound of coal varies so much with the quality of the coal that the fuel consumption in no two mills will be the same. Assuming a coal which, with an ordinary boiler plant, will give an evaporation of, say, 9½ pounds of water per pound, the fuel consumption of the machine itself will be between 0.30 and 0.35 pound of coal per pound of paper made. To this must be added an amount to cover radiation losses in the steam piping, steam used to heat the stock, dry the machine-room roof, or other processes incidental to the industry, and in winter time, the necessary steam for heating the mill.

The ventilation of the machine room is an unusually important problem. For every ton of paper made, two tons of water must be evaporated and carried off by the air of the room before it condenses on the cool surfaces. There are often two machines in each room, each making a ton or a ton and a half of paper every hour.

One pound of air at 132 degrees temperature will carry 0.1177 pound of water at saturation, or at 80 per cent. saturation about 0.09 pound of moisture. One pound of air at zero temperature and 60 per cent. saturation contains 0.0005 pound of water which may be neglected. For each ton of paper made in 24 hours there will be given off 166.7 pounds of water per hour, which will require 1852 pounds or 460 cubic feet of air per minute to absorb it.

The amount of heat required to raise this air from 10 degrees below zero to 132 degrees above, is found by multiplying the weight of air by 0.2375 and by the difference in temperature, or 142. In addition to the volume of air computed by this method, there must be, in large rooms having no hoods over the machines, more air provided, which in all probability will short circuit and not absorb its proportionate amount of moisture. Many successfully ventilated machine rooms have an air change every two or six minutes. With a properly designed system it is not necessary to change so often.

In the manufacture of ground wood, much heat is generated which manifests itself in the shape of steam in the room. Sufficient dry air must be supplied to absorb this moisture and carry it out. The condensed water from all the machines should be returned to a hot well and used for feeding boilers.

Although it should not be so, it often happens that the engine driving the paper machine gives more exhaust than is needed for drying the paper, or the machine tender thinks it does

not give enough, and turns on the live steam, forcing the exhaust back to the hot well uncondensed. In either case this surplus steam should be used to heat water, first for boiler feed, and then for use in the mill.

Exhaust steam can be made to lift the water to an elevated tank from which the beaters are furnished, or from which the supply for washing stock is drawn. The discharge from a condenser is warm enough to be of great assistance in this way. Also the drips from the multiple-effect evaporators used in the soda reclaiming process, are valuable for washing stock. In fact, it is by looking after the many small economies, and substituting as far as possible hot water and exhaust steam for live steam, that the fuel bill is reduced.

In soda mills the spent soda liquor which drains from the brown stock is saved and the soda is reclaimed. This liquor contains all the pitch, sap and resinous part of the wood in combination with the soda, together with some free caustic soda and considerable water. It is first evaporated down to a consistency of 40 degrees Beaumé in multiple-effect evaporators. The steam required in this process is considerable, but may be kept a minimum by conserving the heat which the liquor had when blown from the digesters. Exhaust steam may also be used.

The thick liquor is fed to a reclaiming furnace, where the resinous matter is burned out, leaving the soda in the form of black ash, which can be recausticised and again used in cooking pulp. The hot gases from the furnace are utilised under a boiler for generating steam. This boiler should be designed especially for the purpose, as the volume of gases is large and the temperature comparatively low. The boiler setting should be designed to collect the fine black ash which is carried over with the gases. With the proper design, the boilers should furnish sufficient steam for the evaporators.

The wood pulp is prepared by shaving off the bark, which furnishes valuable fuel if properly used. It is usually burned in ovens of special design.

When there is use for exhaust steam as in the paper machines, the highest steam engine efficiency is not always profitable. But for miscellaneous power, where compound condensing engines and high initial pressures and temperatures should be used, the engine is all too frequently a simple non-condensing engine. Engines may now be had which are designed for high pressures and moderate superheat, and where water is as cheap as it usually is in a paper mill, high vacuua will usually pay.

In selecting the type of boiler best adapted for paper mills, the ability to stand a sudden draught of steam should be considered in sulphite and soda mills, as well as the usual conditions of economy, feed water, setting, etc. When the digester has been freshly filled and a large steam valve is opened to heat the contents up to cooking temperature as quickly as possible, many boilers fail utterly. Either the amount of water which is carried over soon dilutes the liquor and prolongs the cooking, or the pressure drops until the digester blows back into the steam line.

Here, again, is an interesting fact. The same relation does not exist between the pressure and temperature of sulphurous acid as does in the case of water. When cooking at a certain temperature the vapour pressure in the digester is not the same as that of steam at the same temperature.

The endeavour has here been made to dwell on those points which are not common to all steam plants, and to indicate the problems which need most attention. An academic solution does not come within the scope of this article. The basis of action should always be a complete and accurate experimental knowledge of the results obtained under existing conditions and of those obtainable with the conditions improved. One scarcely appreciates the great value of carefully collected experimental data until he has had occasion to use them.

SMALL INSTRUMENTS OF MEASUREMENT

By Joseph Horner

NEVER before have engineers possessed such a wealth of measuring instruments as they have at their command to-day. The manufacture of these necessarily lies in the hands of a few specialists, for, before a single accurate instrument can be produced, an expensive plant must be laid down and must be backed up by an extended experience in all that the manufacture involves. The problems met with in very fine measurements are far from being new, but their application to engineers' tools is mainly a development of the present generation.

Those who are familiar with the scientific literature of the later part of the eighteenth and the early years of the nineteenth century know how numerous were the monographs and articles relating to this subject. They teem in the pages of the "Philosophical Transactions," the "Philosophical Journal" and other less known journals. Ramsden's famous dividing engines astounded our forefathers more than 120 years ago, and yet but for the demands of the optical instrument makers, and chiefly for accurate astronomical observations, the dividing engines might have waited a century longer for their development.

Engineers' work was not considered then to be of a sufficiently refined character to require such aids. It was the era of hand work, and that, too, was in its infancy. The graphic accounts in Holtzapffel's second volume on "Turning and Mechanical Manipulation," written about the middle of the nineteenth century, of the attempts of Maudslay and others to produce a fairly true screw, read like very ancient history now, as do the "Papers on Mechanical Subjects," by the late Sir Joseph Whitworth. But the pendulum has swung back, for, whereas the palm for accuracy was held by the optician a hundred years ago, now the engineers equal and eclipse the opticians, as evidenced in the work of Warner & Swasey, of Cleveland, Ohio, in this department, and the work of the Pratt & Whitney Company, of Hartford, in the production of standards for reference.

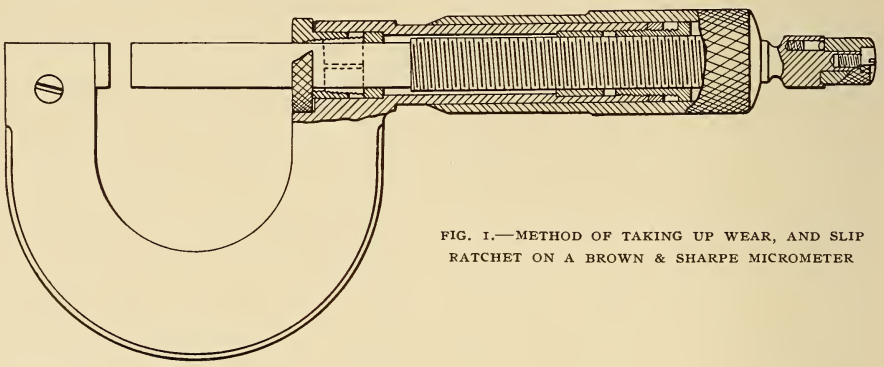


FIG. 1.—METHOD OF TAKING UP WEAR, AND SLIP RATCHET ON A BROWN & SHARPE MICROMETER

It is an interesting fact that though so fine a difference in dimensions as a millionth of an inch could be detected by a feeling piece in the original Whitworth measuring machine, yet the

finest tests for measurement are made by microscopic vision. In other words, rule measurement and not that of gauges is the final test for the finest

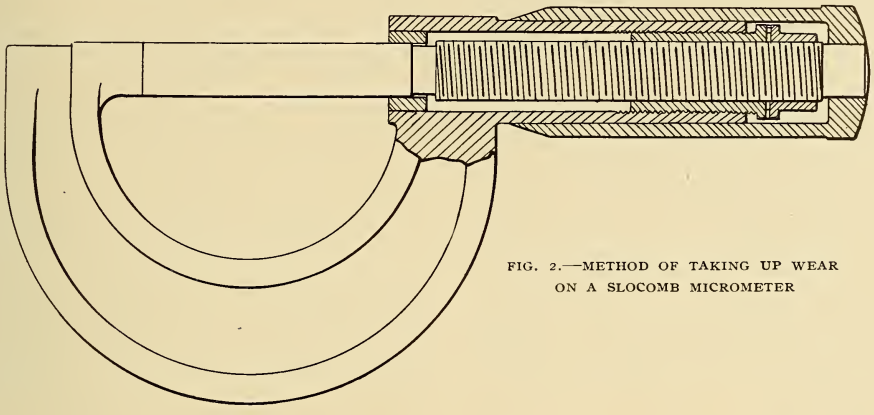


FIG. 2.—METHOD OF TAKING UP WEAR ON A SLOCOMB MICROMETER

degree of accuracy. The various Pratt & Whitney standard bars are ruled and read off by sight, just as with the English standard bars. Yet gauged measurement is that which is mostly resorted to in the practical work of the shops. There are good reasons for such apparently anomalous differences, though both systems exist side by side in the same shops.

The place of gauged measurement is that of fixed and unalterable dimensions, often repeated. That of direct

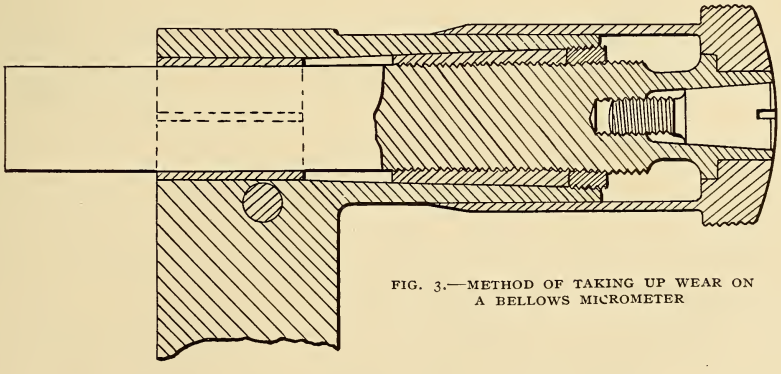


FIG. 3.—METHOD OF TAKING UP WEAR ON A BELLOWS MICROMETER

rule measurement lies either in the manufacture or test of standards, or in the test of sizes that are not embodied in the standard gauges.

For much of the ordinary work of the shops, the rule is accurate enough, but not so when fine dimensions or very precise, though comparatively coarse, limits are required. It is very difficult to work within 0.01 inch by the common rule, but 0.001 is not fine enough for the highest grades of work. Hence we have here the parting of the ways between the gauges depending on the sense of touch and the instruments which embody the application of direct vision. Both now constitute immensely large groups, each including many varieties, but the broad division stated is that which seems most natural to adopt, for however greatly the individual forms vary, they can either be classified under one of these great groups, or they embody a combination of both in one instrument.

Measuring instruments for direct

reading are represented primarily by the common rule. The divisions on a rule, though apparently simple, are the result of a long series of experiments and precautionary measures, having for their object the production of standards. Temperature, which is practically neglected in taking measurements in the workshop, exercises a most important and troubling influence in the preparation of standards, whether long or short. Flexure in long standard bars is another source of variation. It becomes necessary, therefore, in the production of standards to take numerous observations extending over lengthy periods, at constant temperatures. Changes in length also may vary, or become permanent.

The mixture of alloys used is also very important, since coefficients of expansion vary in different materials. If bars of different materials are ruled for standards at the same temperature, they would not measure alike at any other temperatures, and even the same alloys show variations, for of the forty copies of the British Imperial standard yard presented to various governments, only two are standard at 60 degrees Fahr., though all were made of Baily's metal. It is possible to understand this fact in the light of the work of the Alloys Research Committee, bearing on liquations and on the formation of eutectic alloys.

The flexure of long bars, if not guarded against by placing supports at a distance from the centre equal to half the length of the bar divided by the square root of 3, will result in coarse variations from accuracy. Though this may be neutralised by ruling lines on plugs of gold sunk midway into the thickness of the bar, yet the reading of the divisions is rendered more difficult. Standard bars when once completed are never touched for the purpose of transference of the dimension lines to other standards. This is done by means of a comparator, and from these standards as a basis the commercial rules are divided.

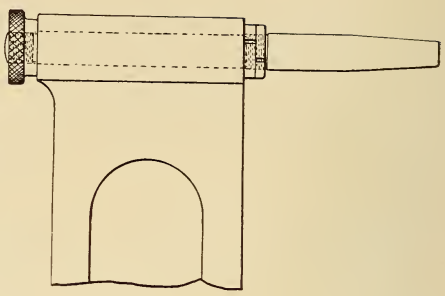


FIG. 4.—METHOD OF FIXING ANVILS FOR LARGE MICROMETERS OF VARIOUS CAPACITIES

The common rule calls for no particular observations, as it is not a fine instrument of measurement. It is used for measurements which are rough by comparison with those effected by the gauges, and is employed chiefly in lining out work for the ma-

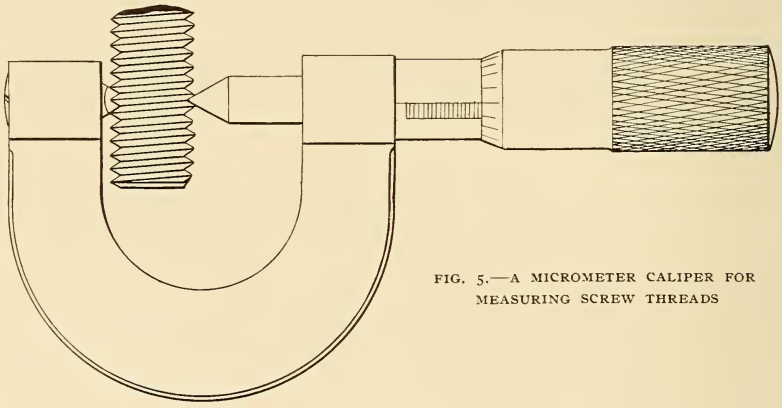


FIG. 5.—A MICROMETER CALIPER FOR MEASURING SCREW THREADS

chines. This statement may seem self-contradictory, but the fact must be borne in mind that work is seldom tooled by the lining out alone. This generally affords an approximation only, to be supplemented by the test of gauges and templets.

To make the rule an instrument of precision, it must be combined with something embodying special provision for minute measurement, as a sliding gauge, fitted with a vernier, or micrometric additions. The result is the same whichever of these methods of fine subdivision is adopted, each being applied indifferently to calipers and movable gauges of various types. In each, 0.001 inch can be read off precisely without magnification and halved with a little careful scrutiny.

clude compass points. The micrometer is also applied to rod gauges for bores. The methods of fitting by different makers are varied with price and ideas. Many of the German instruments differ in design from those made in America, possessing details not found in the latter.

When instruments are designed to measure precisely to 0.001 inch, an obvious difficulty is the retention of that accuracy in spite of wear. This is one of the details in which the designs of micrometers vary. The instrument has a plain appearance outwardly, but, when taken apart, the complexity of some devices is apparent. Some examples of these are shown.

Fig. 1 shows the method of taking up wear of the screw in the microme-

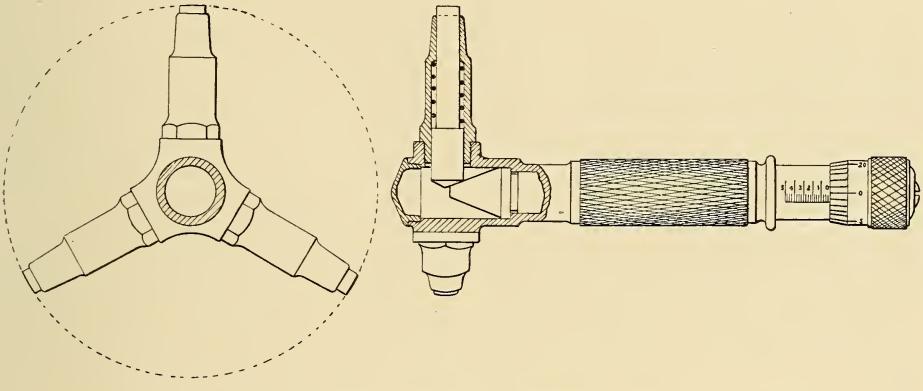


FIG. 6.—NEWALL INTERNAL MICROMETER GAUGE

But the instruments so modified fall out of the category of rules proper, because the application of these refinements is only adaptable to comparatively short dimensions. They do not therefore take the place of the common rule in the work for which it is chiefly employed, but supplement it in checking small dimensions, and so do in variable sizes what the fixed gauges do for fixed dimensions.

There is, however, a vast deal of work lying within the range of these sliding calipers. Both vernier and micrometer fittings are put on similar instruments, such as calipers, and depth gauges, and sometimes the calipers in-

ters made by the Brown & Sharpe Manufacturing Company, of Providence, R. I. The barrel, which is one with the arm, is bored to receive three sleeves. One situated at about the centre receives the micrometer screw. Another behind it, similarly threaded internally, is also threaded externally to fit within the barrel and is provided with a lock-nut by which it is clamped after the adjustment for wear has been made, the thimble being removed for this purpose. The screw threads in the end collar and lock-nut are finer than those of the micrometer screw, to secure the fine adjustment. The plain, or measuring, end of the screw

spindle receives a split ring, which is closed around it, in spring chuck fashion, by the knurled nut, so locking the spindle after setting to a size.

The ratchet device at the right-hand end comprises a spring pawl, which produces just sufficient friction to allow the thimble to be revolved, but slips when the work is touched by the measuring point. A uniform pressure is thus ensured, which eliminates the personal element, since no two men will use quite the same pressure in turning an ordinary screw, which may be tightened too much or not enough.

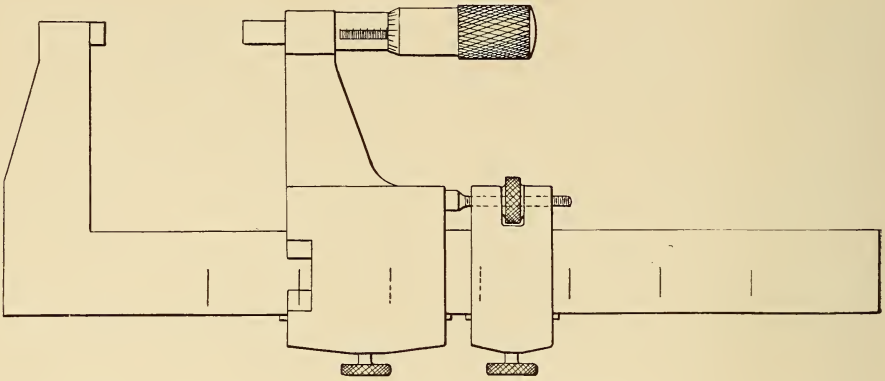


FIG. 7.—MICROMETER CALIPER IN WHICH THE SLIDING HEAD IS SET BY LINES

Fig. 2 shows the micrometer made by J. T. Slocomb & Company, of Providence, R. I., in which the differential screw principle is also embodied, but in a different fashion. The barrel receives a bush at its rear end which is threaded to fit the micrometer screw, and to fit a thread of another pitch on the interior of the barrel. A nut behind is used for adjustment on the removal of the thimble, retaining its position by fine ratchet teeth milled upon the abutting faces of both nuts. A fine coiled spring, occupying a recess between the two, maintains an even tension.

Fig. 3 shows the Bellows micrometer, made by the Athol Machine Company, of Athol, Mass., in which is used a split bush threaded to fit the micrometer screw and tapered on the outside to fit the tapered bore of the barrel. The nut behind it forces the bush into its seating. The spindle is clamped, when set, by a split bush in front, tightened with a cam pin. The tapered and screwed plug at the extreme right of the thimble is used when adjusting to compensate for wear of the anvil face and spindle end. This is done by

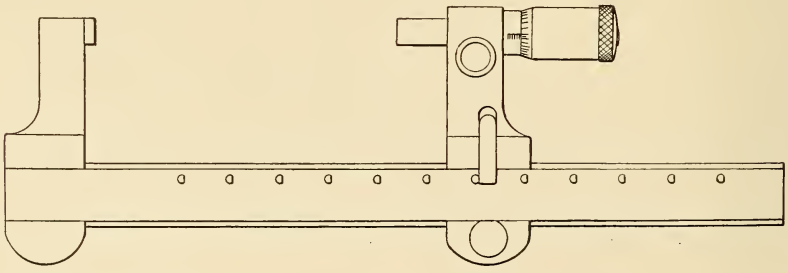


FIG. 8.—A BELLOWS BEAM MICROMETER CALIPER IN WHICH THE SLIDING HEAD IS ADJUSTED BY PINS INSTEAD OF BY LINES

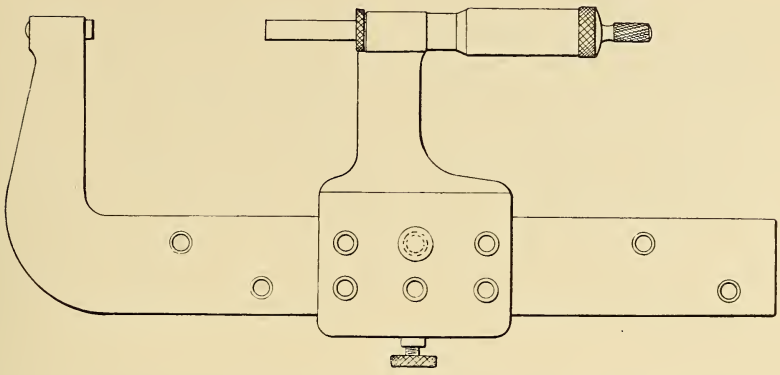


FIG. 9.—BEAM MICROMETER CALIPER ADJUSTED BY PLUGS INSTEAD OF BY LINES OR PINS

turning the thimble to bring the graduations to zero, after which the tapered plug expands the spindle end into the thimble, so locking the latter firmly.

Anvils are usually adjusted by turning them in their screwed seatings, using a disc gauge as a standard, and tightening them when correct with the screw below. The horseshoe forms of micrometers are the most common, the designs being varied by making them double ended, with two sizes at opposite ends, so that dimensions of two inches and all below can be measured. An ordinary two-inch micrometer does not go below one-inch sizes, owing to the limited travel of the screw. Another variation is similar to that of the limit gauges, two separate spindles being combined in one horseshoe.

When dimensions of two or three inches are exceeded, the ordinary micrometer calipers are unavailable, because it is necessary to limit the travel of the screw to within one inch. To meet the increasing demand for larger ranges is the object of the large types with removable anvils, varying generally by one inch in length. Either one of the set furnished can be inserted in the head as shown in Fig. 4, and each has its own lock nuts for the purpose of adjustment from time to time, standard measuring rods being employed in setting.

Fig. 5 shows a special form of the micrometer caliper used for screw gauging. It is more delicate than the ring gauges used for a similar purpose, because it does attempt the almost impossible task of perfect contact all round the circle and at all

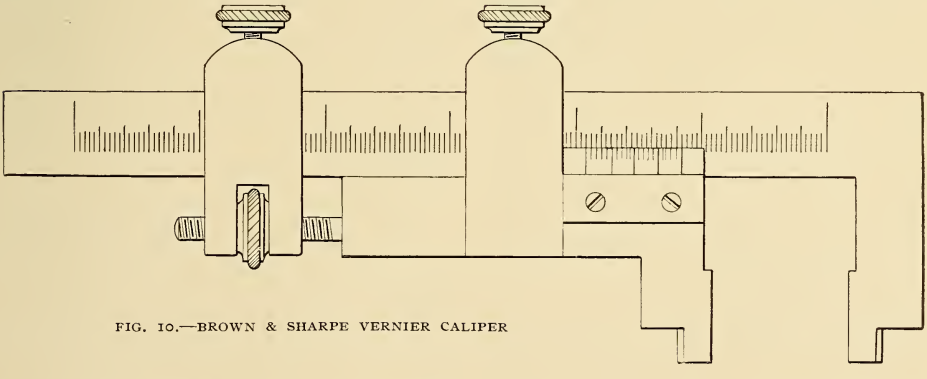


FIG. 10.—BROWN & SHARPE VERNIER CALIPER

sections of the thread. The points and roots of threads do not affect the result, since measurement is taken down the sides and at one-half the depth of the thread.

The micrometer is fitted to internal rod gauges, being a refinement on the rigid gauges which are used for measuring bores. The objection to these forms is that, unless care is exercised in setting them exactly across the diameter, the reading will not be exact. Lately they have been improved, as in the instrument made by the Newall Engineering Company, Ltd., of Warrington, England, with three equidistant measuring points, shown in Fig. 6. Each point is moved in unison by the conical end of the micrometer spindle, contact with which is maintained by means of springs.

The limitation of the small horseshoe calipers in regard to length is the reason for the designing of the beam instruments. The methods of setting these vary,—in one kind, shown in Fig. 7, the sliding head is set to inch divisions on the beam by means of a line on a bevelled edge on the movable head. Minute setting is secured by a separate block clamped to the beam approximately, which then affords a point of resistance to a fine adjusting screw with knurled nut. The micrometer takes charge of the fine fractional parts of an inch. The advantage of this method is that no wear can affect the lines and produce errors in the inch settings. Simplification of setting, with more chance of accurate results, is, however, sought by employing plugs or pins, which do not depend on vision for correct setting. In the Bellows instrument, shown in Fig. 8, pins are set at every half inch in the beam, and a stop standing out from the sliding head is brought into contact with one of these pins. Locking is done by a screw and gib on the loose head, clamping the head to the beam. The edges of the latter are bevelled, and the sliding head fits on the edges and one face only.

In the design shown in Fig. 9, made by the L. S. Starrett Company, of Athol, Mass., the plug device is employed to simplify manufacture and nullify the effects of wear as much as possible, each hole in the beam having its corresponding hole in the head. In fitting the head, therefore, each set of holes, being lapped out correctly, need not be further touched, but attention is directed to the next set, which would not be the case if only one hole in the head had to be used for setting the plug in each beam hole. Wear is also reduced by using six holes instead of one.

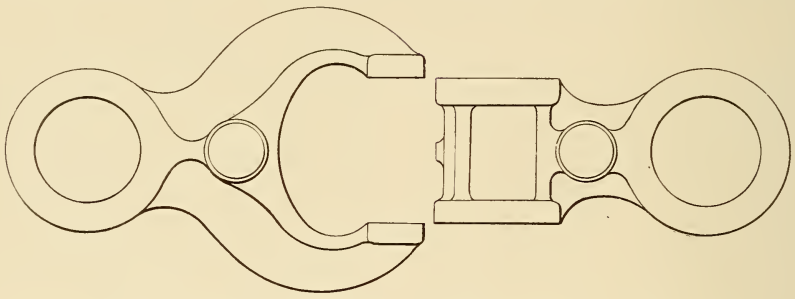


FIG. 11.—SEPARATE EXTERNAL AND INTERNAL STRAP GAUGES

Fig. 10 shows the vernier caliper, which resembles the beam micrometers in its capacity for measuring a length of several inches combined with thousandths. It has means of fine adjustment for such settings by a separate head fitted with a fine screw and nut. Internal as well as external measurements can be taken. The details in design of these are varied and numerous.

In the fixed gauges we have the

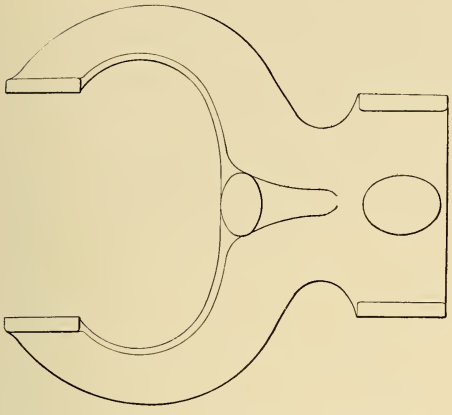


FIG. 12.—COMBINED EXTERNAL AND INTERNAL STRAP GAUGES

great divisions,—standard, limit and adjustable, the last two being later refinements. There are, besides, the divisions into circular and flat forms, or "plug and ring" and "snap," as shown in Figs. 11, 12 and 13. As all engineers are familiar with these groups, we need not offer any explanations of these differences, but give attention to some practical issues.

The most absorbing present question, and one that affects all departments of machine shop practice, is that of limits of tolerance and how they can best be determined and embodied. These vary in different shops, and in the same shops on the different classes of work done, and yet the present need for economical production renders necessary the application of gauged methods in every shop, without exception, in all cases to which gauging can be applied. Hence the great importance of the determination of suitable limits for different classes of work. Let us see in brief what this involves.

There is first the tight fit, variously termed driving, or press, or force, or push fit, meaning that a shaft or a spindle has to be driven or pressed into a hole in a pulley or wheel, or other boss, or the latter be pulled over its shaft. Different from this is the running fit, which is, however, not one, but includes many, from fairly close to very free and loose. Here the great variations are found in practice, —the differences between the rough contractors' plant and the high-class machine tool, or between the loose fit of an axle or shaft journal and that of a lathe mandrel, between the crane and the precision grinder, or the mortar pan and the milling machine. And yet for each there should be set a limit to tolerance which must be adhered to in all the work of the same class done in the same shop. This is one of the later developments of gauged work.

Only a few years since, and in many shops still, these limits were left wholly to the discretion of the workman, even though the work was being done to gauge. The gauges were all standard, and their fitting was full or bare, easy or tight, for all the tight and running fits made. Actually, as far as results were concerned, this was not gauged work at all, because if the limits are not fixed, nothing can interchange when repairs are necessary, or even when work is being produced in sets. The gauges also are badly served and soon lose their original truth, for nothing impairs the accuracy of these instruments so quickly as employing them on rough service on all classes of work.

A man who is regularly doing the same class of work is able to produce very fine results with standard gauges, both in force and running fits; but he might be relieved of some anxiety if supplied with limit instruments. On the other hand, the great objection to limit gauges has been the wide range in which they are wanted if adopted as a system. This range includes not merely the broad different classes of

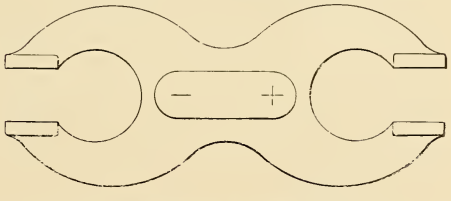


FIG. 13.—PLUS AMD MINUS EXTERNAL LIMIT GA

fits, as force and running, but different limits for bores of different diameters. The allowance for force fitting a two-inch shaft, for example, is not the same as that for a six-inch. Neither are the running fits alike for

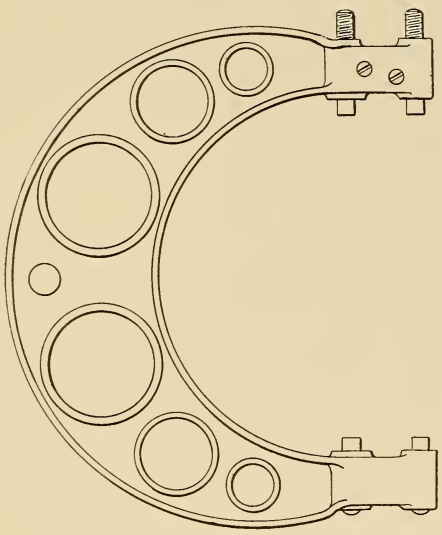


FIG. 14.—NEWALL ADJUSTABLE LIMIT GAUGE

different diameters. But if the system is introduced it must be done absolutely, and different sets of gauges made for every varying kind of fit on the same size, in addition to the coarser limits required as sizes increase. The problem then is how best to cut down these variations and reduce the number of gauges to moderate bounds.

Further, in the practice of some highly specialised shops, the work of turning is divided into two groups done by different sets of men on different lathes, or again between lathe and grinder. This gives rise to another class of gauges, the "roughing," in which the limits may be 0.01 inch or thereabouts. It is because of these numerous variations that the single set of standard gauges is retained in preference to incurring the cost of several sets. The alternative of either is the adjustable gauges, shown in Fig. 14, which have been coming into considerable use recently. These are adjusted and set by measuring pieces, or micrometers, the former being provided in sufficient range to cover all the grades of fits required in the most exacting practice.

The snap gauges are generally taking precedence of the plug gauges in present practice. The reason is that the area over which contact takes place is much smaller in the former than in the latter, and therefore finer accuracy is possible. The case is paralleled in the measuring of cylinder bores with rod gauges, which touch only on what is practically a point, and of external and internal measurements with common calipers, also with points. The plug and ring gauges, though circular, are not expected to check the circular truth of work which is presumed to be correctly machined, but only its diameter; therefore the circular form has no advantages.

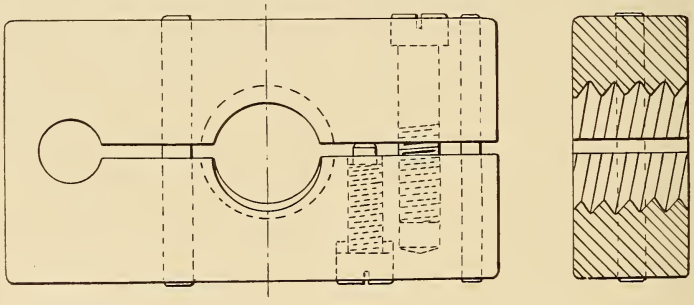


FIG. 15.—ADJUSTABLE SCREW THREAD GAUGE

But apart from this, the ring gauges are unsuitable for large quantities of

work, because they must be slid over from the end. Hence, if there is a shouldered recess between larger diameters, the snap gauge alone can be

FIG. 16.—THREAD GAUGE FOR BORE AND SCREW

used. Moreover, in lathe and grinder work between centres, the ring gauge can only be used by running the loose poppet mandrel back, slipping the gauge over one end of the work, and letting it rest in the intervals on the mandrel or on the work, neither of which is conducive to the preservation of accuracy. Again, in many cases there is not room for the ring gauge to be used, and a snap gauge which can be held like calipers at any position from vertical to horizontal is found adaptable. When large sizes are to be checked, the plug and ring gauges are out of the question, but snap gauges are used up to two feet or more in span. Snap gauges are also more easily corrected for wear, since they can be set in with hammer blows and re-ground to size, or in adjustable types by screws provided for the purpose.

Fig. 15 shows an exception in the case of screw-thread gauges, which for ordinary service are made circular in plug and ring forms, the former of which is shown in Fig. 16. These are very necessary when screw threads are being cut in lathes, where the tools have to be set in for diameter and angle by measurement and gauge.. Very minute variations will suffice to make tight or slack fits between screws and nuts, which the screw-thread gauges detect at once, following the initial trial cuts. Screws produced on automatic machines are checked by standard gauges before being passed as correct, although this is not attempted during their production, except as a check on commencing and after setting the tools.

These gauges contain several threads and fill up the entire depth of thread, so making many points or areas of contact. It is possible, therefore, for a gauge to fit well as a whole without making contact everywhere absolutely, owing to imperfections in the screw being tested. But this harmonises with ordinary shop conditions, and if anything finer is wanted micrometric methods are still open. But coarser and finer conditions are well met by the production of two classes of gauges, those in which the gauge threads are simply cut on annealed steel, and those in which the steel is hardened, and the threads finished by grinding. The latter cost considerably more, but have the advantages of higher accuracy and of perfection of form.

With regard to the limits of accuracy in gauges, these range from the very coarse amount of 0.01 inch up to 0.0002 inch. Most gauges lie between these, or from 0.0002 to 0.0001 inch of absolute accuracy. But for the universal grinder, such fine results guaranteed would be impossible of attainment commercially.

Hardening is essential, following annealing and rough turning. One of the great difficulties encountered is the alterations which take place in the internal structure of the steel, which requires that the roughed-out gauge blanks shall be laid aside for weeks or months to allow such changes to expend themselves, a refinement in manufacture which does not enter into ordinary engineers' work.

GRAIN STORAGE AND MANIPULATION AT THE QUAYSIDE

WITH SPECIAL REFERENCE TO THE PRACTICE AT BRITISH PORTS

By Brysson Cunningham, B. E., Assoc. M. Inst. C. E.

THERE are few, if any, natural products of greater importance than grain. It is valuable not only on account of the magnitude of commercial operations in it, with their enormous monetary equivalent, but also because of its universal indispensability to the conditions of human existence. Many other forms of food may be, and often are, foregone, but the "staff of life" must be numbered among the things which are absolutely and essentially needful to mankind.

The working classes, who constitute the great bulk of the population, consume on an average something like 4 or 5 pounds of bread to 1 pound of meat. When domestic funds run low, the quantity of meat is reduced, but the consumption of bread remains the same. Obviously, then, the growth and harvesting of cereals is a matter of world-wide interest. For the present, however, let us turn our attention from this aspect of the subject to the attendant and no less important problem of grain distribution.

The inhabitants of the world and its corn fields are unequally divided, and means must therefore be found to make good the deficit of grain in populous centres by the surplus production of sparsely inhabited tracts. Thus the steppes of Russia are called upon to minister to the densely crowded courts and alleys of London, and the pampas of Argentina to the clustering industrial centres of the Netherlands. The fate of many a country would be disastrous if it were deprived of its external supplies, for while Russia, Argentina, India, and the great States of North America produce largely in excess of their local needs, the majority of European countries are unable to meet the wants of their teeming populations.

The following statement is a rough approximation of the world's demand and supply of wheat at the present date. The quantities, however, which are stated in millions of quarters, are, of course, liable to considerable fluctuations from time to time :—

Country	Wheat Crop 1904	Probable Surplus for Export 1904–5	Probable Deficit to be Imported 1904–5
Great Britain.....	5	..	26
United States.....	67	6	..
Russia	60	19	..
France	37	..	3½
Austra-Hungary	24	..	..
Germany	17	..	7
Italy	16	..	5½
Spain and Portugal.	11	..	2
Balkan States.....	11	4½	..
Canada	10	3	..
India	40	9	..
Argentina	15	10	..
Australia	7	3	..
Holland & Belgium	25	2	8
Scandinavia			2
Other countries.....			10½

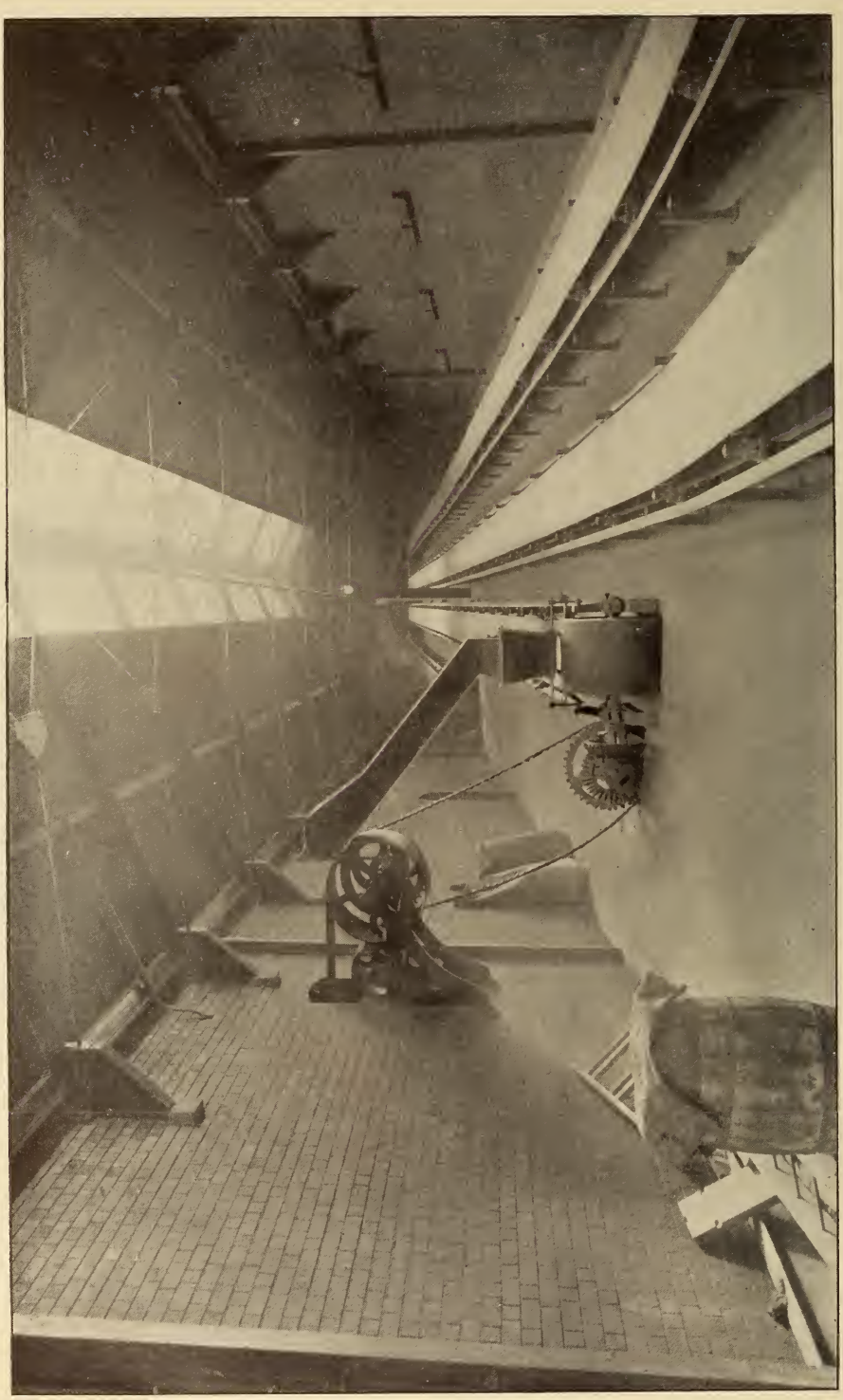
The most striking feature of this table is the manifest dependency of Great Britain on foreign production. In no other case is there so marked an inability to balance home consumption by internal supplies. Without her imported wheat, Great Britain would speedily be reduced to a state of starvation. Furthermore, it cannot but be observed that this dependency on for-

A DERRICK ELEVATOR DISCHARGING GRAIN FROM A STEAMSHIP, AS INSTALLED BY MESSRS. SPENCER & CO., LTD., MELKSHAM

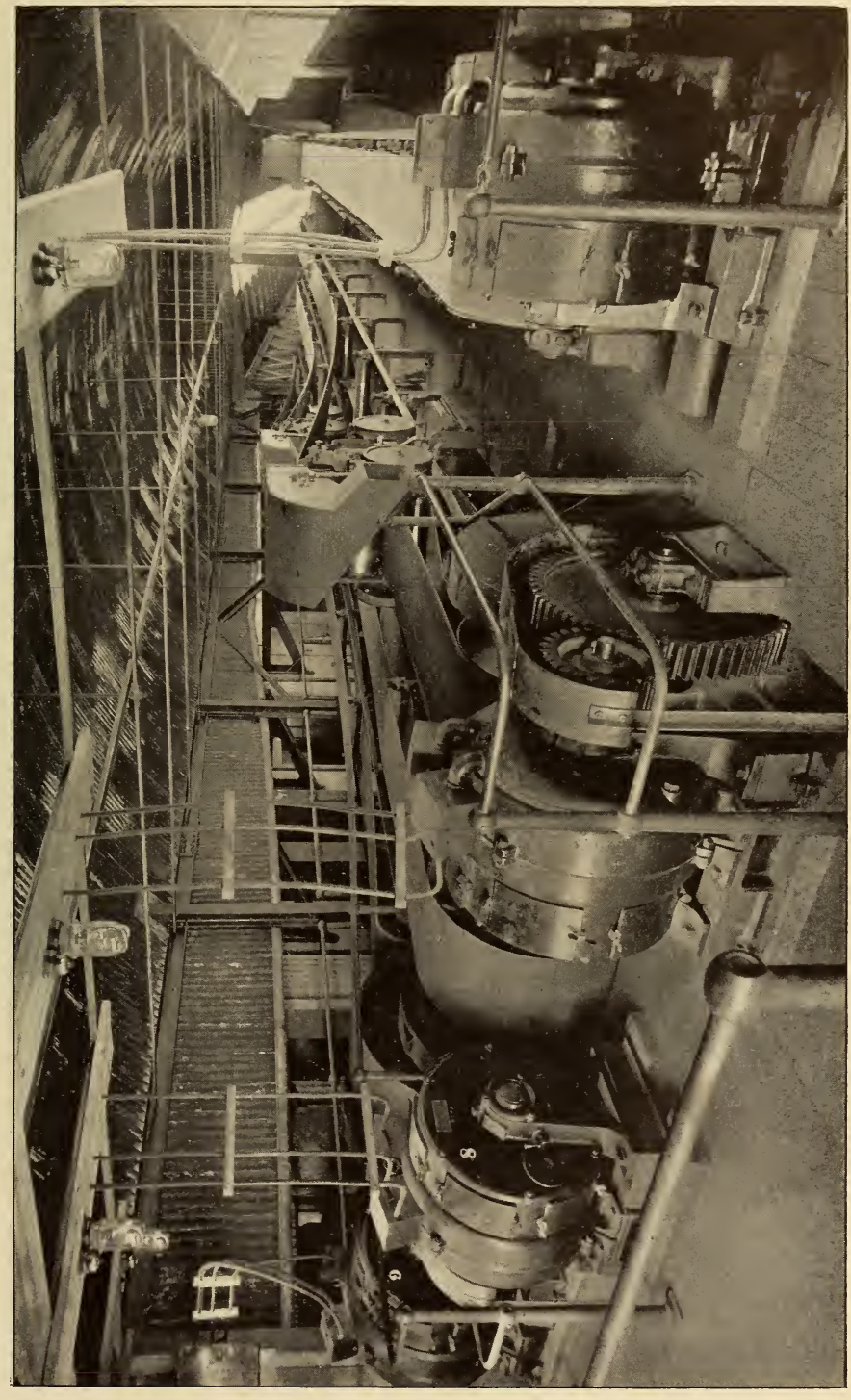
eign supplies is becoming annually more accentuated. In 1903 Great Britain received 356,000 tons of grain more than in 1902, while in grain and flour combined the increase was 441,000 tons.

There is an interesting feature in connection with the sources from which Great Britain derives her bread stuffs. Between one-fourth and one-fifth of it comes from the Colonies,—the remainder from other shores; but the great variability of the harvest in different parts of the globe changes the venue annually. The contribution of the United States to Great Britain, which in 1902 amounted to $3\frac{1}{4}$ million tons of wheat and flour, fell to $2\frac{1}{3}$ million tons in 1903, and the Australian supply of 250,000 tons fell to zero; on the other hand, India practically doubled her 1902 quota of 440,000 tons, and Argentina trebled hers of 225,000 tons.

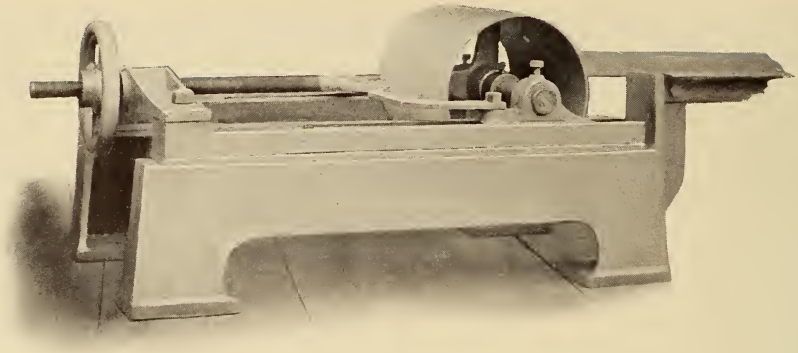
The magnitude of British interests in cereal cargoes of all kinds affords indubitable proof of the supreme importance attaching to granaries for the reception of the cargoes, and the machinery used for their manipulation at



GANTRY BAND CONVEYORS AT AVONMOUTH DOCKS. MADE BY MESSRS. SPENCER & CO., LTD., MELKSHAM



LONG BAND CONVEYORS DRIVEN BY ELECTRIC MOTORS AT AVONMOUTH DOCKS. MADE BY MESSRS. SPENCER & CO., LTD.



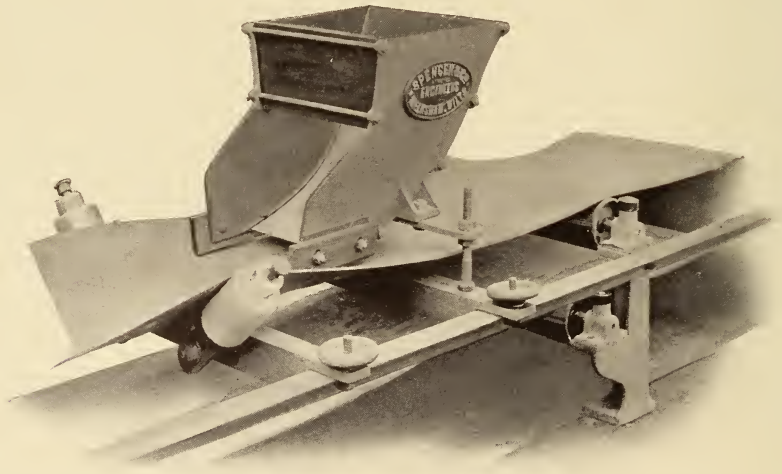
TIGHTENING GEAR FOR BAND CONVEYORS. MADE BY MESSRS. SPENCER & CO., LTD.

the quayside. All ports of any note, in fact, are necessarily equipped in some form or other with appliances for loading and unloading grain, and a brief review will here be given of some of the special features in typical English buildings and machinery.

The various processes of manipulation undergone by grain at the quayside are allocable under three heads, viz.,—shipment and unshipment; storage; and temporary transference for subsidiary purposes, such as sorting, aerating, cleaning, etc.

Weighing is a process which is common to all three divisions. Indeed, adaptability to more than one of the above processes is a feature which is characteristic of several of the appliances in common use; hence it will be convenient to deal with them more in reference to their general functions than as regards any particular application of them.

First of all, however, it is desirable to devote a few remarks to the forms of accommodation in vogue for the reception of grain. Grain storage may briefly be said to be effected on one or the other of two different systems,—the open floor or the silo. In the former case, an ordinary warehouse suffices for the reception of the material, which may be either in bulk or in



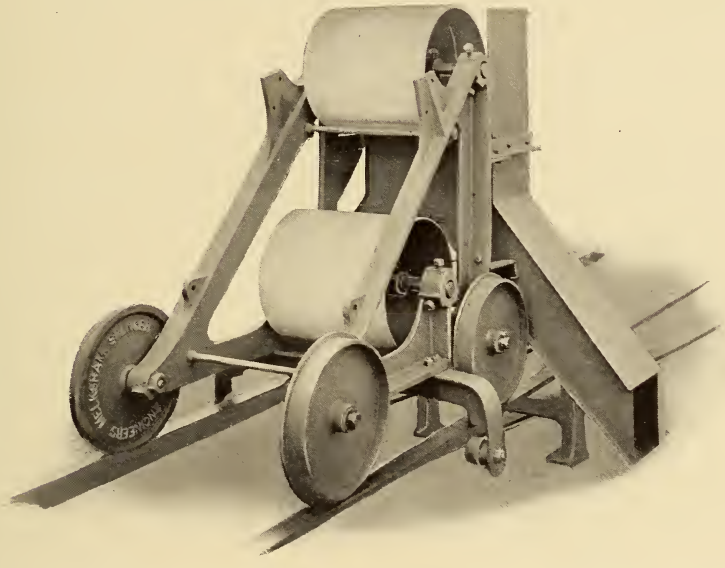
A BAND CONVEYOR FEED HOPPER

sacks; in the latter case, special tanks, bins, or wells have to be constructed, and the deposit is always in bulk.

Of the two methods, preference must undoubtedly be given under modern conditions to the silo. It is convenient and systematic, economical in the matter of space, and it lends itself with great facility to the loading and discharging of its contents. Such mechanical operations as are necessary can be conducted with the utmost ease and efficiency, either in regard to storage or transference, and the proportion of manual effort is reduced to a minimum.

In open floor storage, on the other hand, a considerable amount of manual labour is general, and in most cases inevitable, on account of the necessity for trimming the grain and feeding it to the spouts. It is possible, of course, to make use of pneumatic and hydraulic apparatus for effecting much of the work, but the expenditure of power by the former system is so great as to be a deterrent; the adoption of such apparatus is, therefore, but partial and local, while with any other system, auxiliary hand labour is a necessity to a greater or less degree.

Against this it may be urged that the floor system is advantageous for drying damp grain without the trouble of changing bins, and that warehouses are more adaptable than silos to general uses. Maize or Indian corn is almost invariably stored in warehouses on account of its great tendency towards heating; it often arrives in a heated state from the holds of vessels, and open storage becomes a necessity in order to reduce its temperature. Oats and other grains are also generally warehoused.



THROW-OFF PULLEYS ON MOVABLE FRAME. MADE BY MESSRS. SPENCER & CO., LTD.

For wheat, however, the silo, which, in fact, is only an American revival of the old-time grain pit, is fast superseding in Great Britain the more indigenous system of warehousing. The bins or tanks, as generally constructed, are either square, hexagonal, or circular. Of these forms, the first perhaps is the most advantageous from the point of view of scope and accommodation, while the circular shape is constructionally strongest. The hexagonal may be looked upon as an at-

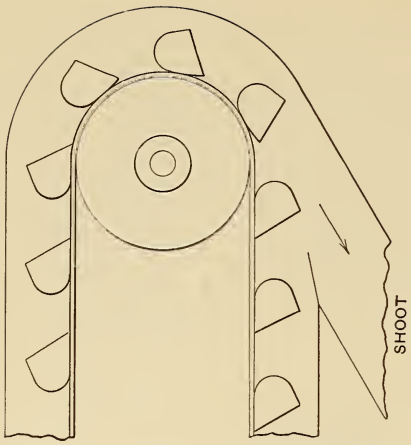


FIG. 1.—AT THE HEAD OF AN ELEVATOR

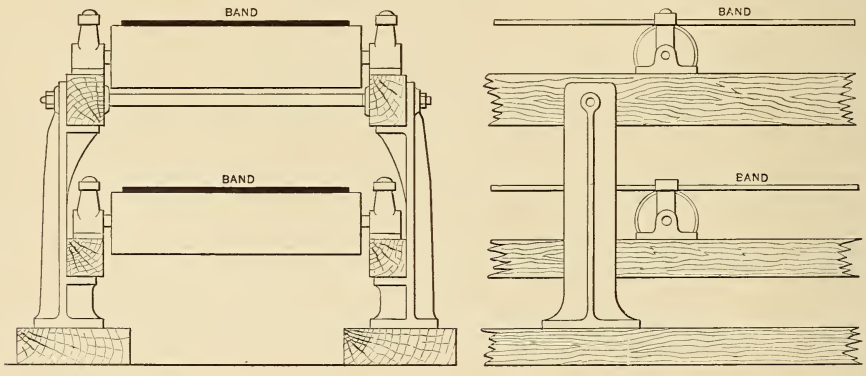
tempt at a compromise between these two extremes, but it possesses a drawback of its own in the increased cost of its construction.

The materials of which silos are built vary greatly,—metals, brick, concrete, and wood have all been pressed into service. Wood is inflammable, but lends itself readily to economical and rapid erection. It is much more characteristic, however, of American than of English practice. In America, timber is cheap and plentiful, and there is every inducement to make use of it; in England, fire regulations deprecate its employment, and forbid it altogether in the case of external walls.

Iron or steel is an equally handy material for constructive purposes, besides being strong, compact, and fire-resisting; it is, however, non-absorbent, and any surface condensation due to moisture in the grain inevitably produces rust and mould. To remedy this evil the interiors of metal bins have been lined or finished with cement, a process which, while satisfactory enough in its results, raises considerations of expense. Brick and concrete are the materials most commonly used for granaries in Great Britain, for, despite their bulk and weight, they are fireproof, absorbent, and poor conductors of heat and cold.

Turning our attention now to the working equipment of granaries, we will consider the subject under two heads, viz.,—elevators, and conveyors.

The first of these two classes of machinery is obviously devoted to the work of raising grain from a lower to a higher level—that is to say, from the bottom of a ship's hold or from the quay to any desired height. The device most generally adopted is that of an endless succession of cups or buckets, working over revolving drums or pulleys set at the head and the foot, respectively, of an erect, rigid frame. The buckets are attached to a belt of leather, canvas or India rubber, or to a sprocket chain, and they rise through the interior of a trunk or cased shaft of wood or iron, receiving their load by dipping into the grain in their lowermost position, and discharging it while passing over the



FIGS. 2 AND 3.—SECTION AND PARTIAL ELEVATION OF A BAND CONVEYOR

pulley at the summit. The buckets are made of sheet metal, and may take the form, either of scoops or plates.

These elevators can be run at speeds as great as 650 feet per minute, but a velocity of from 350 to 400 feet per minute represents the usual working limit for machines with ordinary sized pulleys. The speed, of course, depends upon the diameter of the topmost pulley, since there must be sufficient impetus generated to throw the grain clear over the descending trunk into the discharge shoot, as indicated in Fig. 1. For pulleys of different diameters the following are appropriate linear velocities:—

Diameter in Inches	Speed in Feet per Minute
18	150 to 200
24	200 to 250
30	250 to 300
36	300 to 350
42	350 to 400

From these figures the rule may be deduced that the lower limit of speed in feet per minute is 100 times the diameter of the pulley in feet.

The bottom pulley is not uncommonly of smaller diameter than the top or driving pulley (driving from the top insures steadiness of movement), on account of the convenience of dipping into a narrow "boot" or hopper, but this arrangement has no advantages for small deliveries, and in such cases the movement is parallel. The distance between the pulleys should be capable of adjustment, so as to counteract any tendency to slackness which may manifest itself in the driving chains or belts. On account of lesser susceptibility to such changes, chains are preferable to belts in situations exposed to rain and moisture. They are composed of loose links, which are easily detachable from one another at a certain angle, although they are perfectly secure in the working position. This arrangement admits of the interpolation and abstraction of links, as may be desirable. The buckets are attachable to special links having side lugs or flanges.

Elevators for the discharge of ships' cargoes are located either as fixtures at the quay edge, or alternatively, they are mounted on floating barges. A great deal of grain nowadays is transferred directly from ocean steamer to coaster or lighter without first being deposited on the quay; for this class of work portable elevators find considerable scope. Both quay elevators and barge elevators are fitted with derrick supports and some form of suspension gear to enable them to be projected forward and set vertically in the hatchways of vessels, or at any angle which may be convenient. Fluctuations of tidal level also render it necessary to provide for a considerable range of movement. Accordingly, the

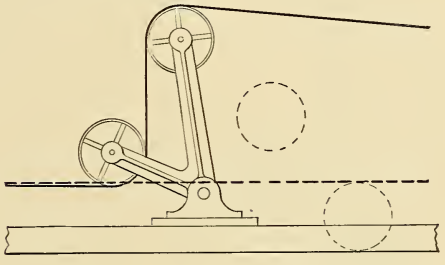


FIG. 4.—THROW-OFF PULLEYS. THE DOTTED LINES SHOW THE POSITION OF THE PULLEYS WHEN THE THROW-OFF IS NOT REQUIRED

elevator is slung over pulleys at the end of a jib or pivoted arm, which in its turn is slung from the derrick head, or the former is counterbalanced by a weighted prolongation.

In quayside granaries, the head of the elevator, generally enclosed in a separate tower surmounted by a cupola, is at such a height as will afford sufficient range for the discharge of grain first into storage hoppers and then into weighing hoppers, prior to its passage along the distributing shoots into the bins or floors. In connection with the "overside" discharge alluded to, from liner to lighter, weighing is achieved by means of the interposition of a portable weighing machine at the head of the lighter. These weighers are automatic and are capable of dealing with from 140 to 150 tons per hour.

Of conveyors, there are many types, but in regard to utility and convenience

A DERRICK ELEVATOR, MADE BY MESSRS. SPENCER & CO., LTD., STOWED, READY FOR TRANSIT TO OR FROM A STEAMSHIP

THE POSITION OCCUPIED WHEN AT WORK DISCHARGING GRAIN FROM A STEAMER

for moving grain, there may be said to be but one of any importance, especially for long distances, and in fact for all distances exceeding 15 yards. This is the band conveyor, which embodies at once the simplest and the most rapid principle of propulsion. Despite some prognostications which accompanied the first appearance of the apparatus, grain manifests no desire to leave the moving surface of a perfectly flat band, and conical and side rollers have long since proved unnecessary precautions against spilling, except perhaps at feeding points; there it certainly is desirable to slightly trough the band for a distance of a few feet, after which it may be allowed to resume its normal level upon horizontal rollers.

The rollers are generally of hard wood in solid form, or of steel in the form of hollow tubes, and are usually from 4 inches to 6 inches in diameter. They are generally spaced about 6 feet apart along the upper portion of the band which carries the load, and double that distance along the return portion, unless that also be used for conveying purposes, in which case the distance is not increased. This arrangement is quite feasible, but less usual perhaps than the single track belt. With the double track, the return is sometimes made at a different floor level with vertical end connections, but more commonly each floor has its own lead and return, with terminable rollers of rather larger diameter than the ordinary rollers, in order to afford space between the bands for feeding and discharging.

SHIP ELEVATOR IN WORKING POSITION

The bands are of webbing and rubber, and are kept taut in ordinary cases through screw adjustments of the end pulleys, by which means the distance between them may also be regulated to some extent. For long conveyors, however, a jockey pulley carrying a weight needs to be interposed at some point in the course, generally in the return length.

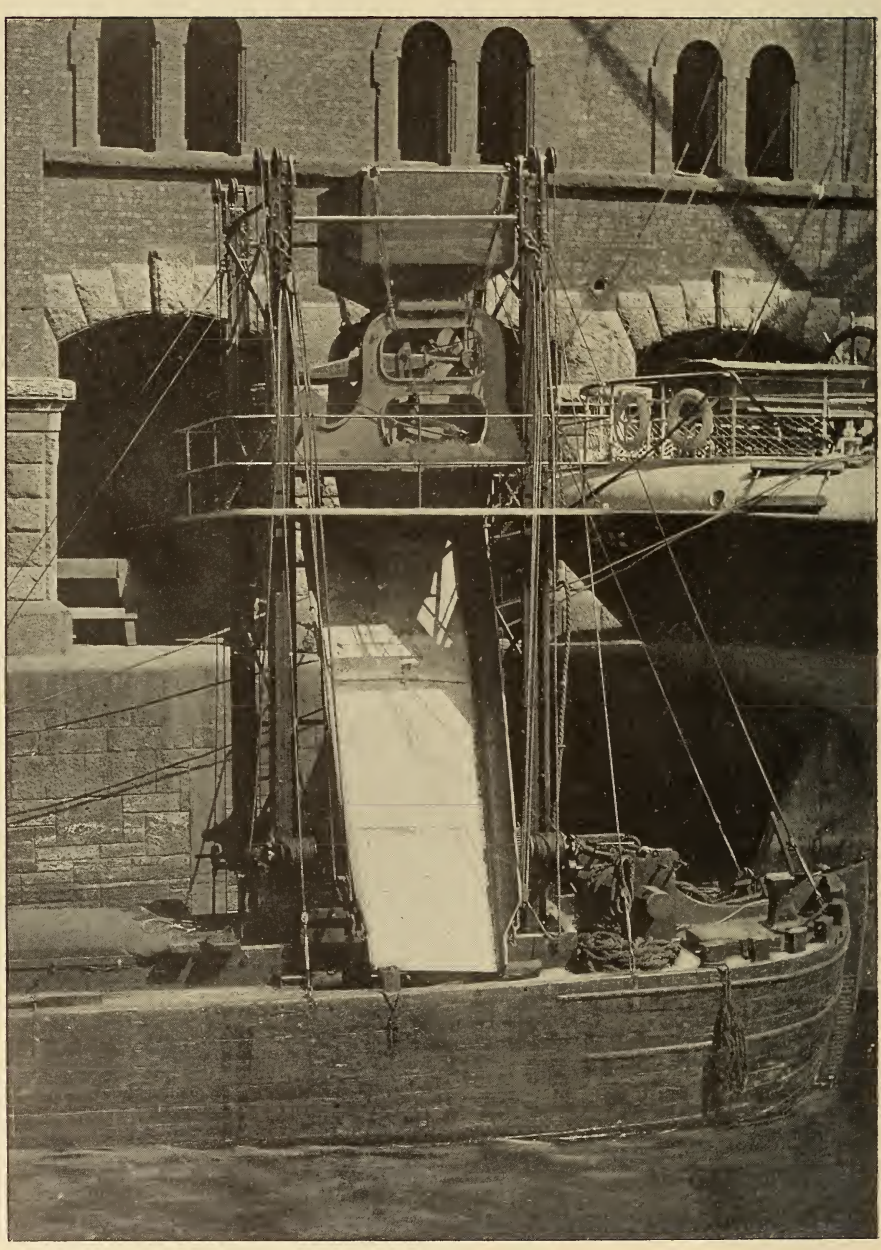
Bands usually run the whole length of a building, and where the warehouse is divided into compartments with brick walls or other fireproof partitions, it is a commendable arrangement to protect the band openings by sliding steel doors furnished with narrow slots to accommodate the band. These doors, of course, are only drawn into position when the band is at rest.

Throw-off pulleys or carriages are an important feature of band convey-

THE SAME ELEVATOR IN HOUSED POSITION

ors. Two guide pulleys attached to a pair of rigid arms, as in Fig. 4, or fixed in a frame, and capable in either case of revolving vertically on an axis or pivot, are caused to alternately raise and depress the band. The grain carried forward by its own momentum passes over the topmost pulley into the mouth of the shoot placed ready to receive it, whence it is deflected at right angles to its former course, and led off in any desired direction. The frame is either fixed or movable, according to circumstances. In the latter case it is mounted on wheels.

Band conveyors for grain run approximately at the same speeds as elevators, viz.,—from 450 to 600 feet per minute, but it is necessary to differentiate between light and heavy material. Thus oats belongs to the former class, and containing a large pro-



AN AUTOMATIC GRAIN SCALE WEIGHING GRAIN "OVERSIDE." MADE BY MESSRS. W. & T. AVERY, LTD., BIRMINGHAM, AND USED EXTENSIVELY BY THE LIVERPOOL GRAIN ELEVATING COMPANY FOR WEIGHING GRAIN IN TRANSIT BETWEEN ATLANTIC LINERS AND SMALLER SHIPS. CAPABLE OF HANDLING 150 TONS HOURLY

A STORAGE GRANARY WITH FOUR INTAKE ELEVATORS AND WEIGH HOUSE AT AVONMOUTH DOCKS

portion of husks and chaff, is liable to be blown off the carrier if the speed exceeds 500 feet per minute, but Indian corn, or maize, can be transferred at the higher speed without any such likelihood of displacement.

The worm conveyor is also applicable to grain transference. It works at a much lower speed than the band conveyor, and is more exacting in the matter of power. At the same time it has certain advantages in the way of cheap construction for short lengths, and if of the tubular variety it may be used for conveying grain across the space between two adjoining buildings without the use of a bridge or other support, being self-sustained when stiffened by suitable trussing.

There is one type of apparatus which discharges the dual functions of elevator and conveyor without coming precisely within the category of either. The apparatus in question is based on pneumatic principles, and acts on the grain by suction and propulsion. One type of the system, and perhaps the best known in Great Britain, is that devised by Mr. Duckham, the engineer of the Millwall Docks, London. By his system the grain is sucked up through flexible tubes and passed into other tubes, which discharge it at any desired point.

Its principal advantage lies, perhaps, in connection with the exshipment of grain, as the suction nozzle and feed pipe are adaptable to all the sinuosities of a varying load, and manual trimming of the material is obviated. For lifting grain in the ordinary way on the quay, the advantages over the bucket elevator system are not so marked, and the working cost is higher. This last fact militates against its popularity. Still it is a valuable invention, and there should be plenty of scope for its employment on a floating plant for the transfer of grain overside.

Limiting space necessarily precludes any allusion in the present article to the particular use of appliances in con-

nection with milling, yet there is one point appertaining to this department of grain manipulation which should not be omitted. This is the very marked tendency in recent years to erect flour mills at the quayside, in contradistinction to the older system in which they were usually situated some distance inland. Obviously, by this method, there is a great saving of expense, since cartage and handling are to a very great extent, if not altogether, abolished. A mill situated on the quay, or wharf, in direct communication with an adjacent granary, not only receives its supplies conveniently and promptly, but is enabled to despatch the milled produce to its destination by water or by rail with a minimum of intermediate handling.

This change of policy has been very noticeable in the case of one flour-milling centre—Liverpool—which is now probably second only to Minneapolis, in the United States, in the extent of its milling operations. Quayside mills are springing up at the docks on both banks of the river Mersey, which flows into Liverpool Bay, and there bids fair to be continued enterprise in this direction. Moreover, the movement is spreading to other ports, with every prospect of becoming general.

SAFETY IN AMERICAN RAILWAY TRAVEL

By Day Allen Willey

DURING the three years ending with June 30, 1904, reports of railway companies in the United States show that 1044 passengers and 9116 employees were killed; 22,139 passengers and 115,981 employees wounded, making the death list average 3387 yearly, and that of the injured, 46,040. Adding the number of other persons killed on grade crossings and in other accidents, the yearly fatalities resulting from transportation service in this country now aggregates nearly 10,000.

These statistics in themselves are so startling in their proportions as to warrant the questions,—Why should there be such an appalling mortality, considering the boasted efficiency of American railway systems? To what causes are due the disasters involving this great loss of life? When compared with the records of other countries, these questions have far more significance, for the American death roll more than equals those of the United Kingdom and Continental Europe combined.

In comparison with Great Britain the accident record for 1903 reveals the fact that only 25 passengers were killed and 769 injured on the British lines. That this was not an exceptionally fortunate year is shown by the list during the three previous years, in which the aggregate number killed was but 22, the total number of injured being 2071. During the year of 1901, not a single passenger met death on the railways of Great Britain or Ireland. In 1903, according to the reports of the Interstate Commerce Commission, the record of passengers killed in the United States was 321, while in 1902, 303 lost their lives, the number of injured being 6973 and 6089, respectively.

The disparity in mileage may suggest itself as an argument that the casualties are less numerous in the United Kingdom, but while it is true that its railways cover about ten per cent. of the distance over which American lines extend, the traffic is so much greater in proportion that the number of tickets sold in a year is nearly five-hundred million more than in the States. In 1903 British travellers by rail numbered 1,194,000,000, excluding persons riding on monthly or commutation tickets, and on all urban railways. In the British service the speed attained and the frequency of train movement is equal to if not better than the service on the highest standard systems of America between the large cities. The number of passengers moved indicates how closely trains must follow one another, and the necessity for the utmost caution in their control, but such is the efficiency maintained, that express schedules between London and Edinburgh enable one to make the journey of 400 miles in 420 minutes,—an average of nearly 60 miles an hour. The London & North Western Company carries the homeward bound tourist from London to Liverpool, 195 miles, in 4 hours on its "steamer" trains.

In analysing the causes of fatal accidents in the United States, that due to trespassing seems to be unavoidable. The companies cannot be

blamed for the maiming and killing of persons who trespass on the right of way, since the length of roadbed is so great that it can only be partially protected; on the Western prairies, however, and in other sparsely settled localities, not even a fence separates the track from adjoining country. The pedestrian can readily make a pathway of the tracks, and so common has become the custom that it has claimed a large number of victims.

The grade crossing is another prolific cause of fatalities. It is obvious that such accidents would be numerous considering the number and variety of the crossings, and the crude safeguards with which so many are protected. In addition to the ordinary highway grade crossing, many street and suburban electric railways have, in recent years, been constructed at a grade with the steam lines. As yet but very few junctions of steam railroads in the suburbs of large cities have been avoided by elevating or depressing an intersecting line. The cities of Buffalo and Chicago have nearly eliminated such crossings, while the Pennsylvania Railroad Company has recently completed a very important improvement between Jersey City and Philadelphia by which its trains are elevated above the highways as well as railways in all of the populous communities through which it passes. When it is stated that not a single system in Great Britain is constructed at a grade with any of the thoroughfares in the towns it traverses, one can realise the great advantage of British transportation service in this respect.

Unquestionably a very large percentage of accidents could be averted by the installation of automatic gates operated by compressed air or electricity. They are automatically regulated by the passage of trains, being lowered as a train approaches and raised as it leaves the crossing, but thus far only a few have been placed in position; it is a fact that fully one-half of the highways in the United States have no safeguard whatever, save a sign post at points where they cross the track.

Other notable causes of accidents outside of the ones previously mentioned, are found in derailments, defective equipment and collisions. Under the head of defective equipment may be placed faulty bridges and other elevated work. In considering the first it is necessary to refer briefly to the changes which have been made in the construction and equipment on railroads in America within the last 20 years. The days when standard gauge railways were laid with rails weighing 50 or 60 pounds to the yard have passed away, and this size is no longer considered suitable for the types of locomotives and cars now built. The lightest rail on the larger systems is expected to weigh at least 70 pounds to the yard, while on curves and grades it ranges as high as 100 pounds. Ten years ago the ordinary coal and ore car carried but 35 tons, and the little "jimmies" holding 10 or 15 tons were still in use.

Now, we have the car composed entirely of steel or of steel framework, which will hold from 50 to 55 tons. Thus the weight of the freight train has increased, until the locomotive is now designed to pull a load of 1500 tons or more, except where the grade is of unusual percentage. In passenger service the transformation has been perhaps greater. Not only the Pullman, but the ordinary coach has been enlarged and more and more metal is used in its construction. The express locomotive on the principal railway systems is capable of hauling a train of 500 tons at an average speed ranging from 40 to 50 miles an hour for distances of 100 miles and over. This means that on down grades and on straight stretches of track the locomotive must frequently attain a speed of 70 or 75 miles an hour in order to maintain schedule time and allow for the various stops.

So rapid has been the development of traffic, that in the Eastern portion of the United States, especially, many of the railways have been wholly or

partially reconstructed,—the roadbed has been regraded and reballasted, heavier rails have been laid, and bridges and culverts have been replaced by more massive structures. In some instances, however, the reconstruction of the roadbed and track has not kept pace with the increasing size of the rolling stock, and to this reason can be attributed a number of casualties. It has been said that bridge engineering has reached a higher standard in America than in any other portion of the world. Whether this be true or not, certain it is that American lines have steel structures which vie in length and strength with any metal viaducts in existence, but in employing these structures the question of vibration is of the greatest importance.

Speed must be greatly reduced in crossing the heaviest structures, as beyond a certain rate vibration becomes dangerous. Exposure to the elements and the strain of train service necessitate frequent inspection of every portion, and unless the material is properly protected by painting or other means, the bridge may be a constant menace to traffic. In this respect British railways have a decided advantage, since many of the viaducts are of masonry, permitting the movement of trains over them almost as rapidly as on a solid roadbed.

With a roadbed equal to the requirements of service, the increase in weight of rolling stock tends to avoid accidents due to derailment, as the greater load on the trucks gives the wheels more adhesion, but the condition of rails and ballast is a most important factor. If the rails are insecurely spiked and the ballast too light, the strain caused by the movement of a heavy express running at 50 miles an hour may cause spreading. The enormous pressure developed at high speed has been demonstrated on the German experimental line between Marienfeld and Zossen. It was necessary to lay the track with 100-pound rails, bolted to metal ties, and make the roadbed practically solid by setting the ties in concrete before it was strong enough to permit the electric train to move at the rate of over 100 miles an hour.

Maintenance of way and structures forms one of the greatest items of expense in rail transportation. It has been maintained that to keep the line up to the proper standard fully 150 men should be apportioned to the section gangs on every 100 miles, and the annual outlay for repairs should range between $500 and $1500 per mile, depending on the character of the rolling stock and the frequency of train service. Too often, however, the company attempts to economise by reducing its force of trackmen and by delaying improvements essential to safety, such as repairing roadbed and renewing rails and ties. Herein is a source of not a few disasters which have been far more costly in damage suits than the outlay for the betterments would have represented.

But criticism has been chiefly directed against the American railway companies because of the numerous "train accidents," nearly all being head-on or rear-end collisions. The year 1904 was especially notable for the extent of these casualties, in which 270 passengers lost their lives,—nearly 65 per cent. more than during the preceding year. It is a fact of much significance that the great majority of these accidents were on roads not equipped with the block signal system, and where all trains were controlled by telegraphic communications from the train despatcher at the end of a division.

Thus far only 40,000 miles of main line in the United States have any method of block protection, although of the 220,000 miles of main line less than 20,000 are double-tracked.

The comparatively small number of casualties in the United Kingdom, and the fact that collisions there are almost unknown, make the British methods employed for train control of special interest to Americans.

Generally speaking it may be said that the division of British railways

into sections or blocks, each controlled by signals, is the principal safeguard. The block systems on the double-track roads are known as manual and automanual. In the manual system each signal man controls the apparatus at the station where he is located, but his work is verified by the operator at the next station.

To give a comprehensive idea of the method of operation, we will suppose that a train is at station No. 1, ready to enter the block between No. 1 and No. 2. The signal man at No. 1 communicates with station No. 2 by means of an electric bell. The operator at No. 2 ascertains whether the train is a passenger or goods train by the number of strokes on his bell, which precedes what is known as the warning signal that the train is ready to enter the block. No. 2 repeats the call given by No 1 to show that he understands it, and must also signal whether the right-of-way is clear. If clear, then the engineer of the train is notified to go ahead, and as soon as the train is in the block, No. 1 signals this fact to No. 2, who repeats the signal and then notifies station No. 3. As soon as the train passes station 2, the operator gives the signal, "line clear," to No. 1, who repeats it to show that he understands, and then sets his signal to indicate that the block is closed until the next train approaches, when the operation is repeated.

The apparatus employed consists of the electric bells already referred to, and a dial. Over the face of the dial moves a hand or pointer. On the dial are these phrases, "Line clear," "line closed," and "train on line." When the operator at station 1, for example, moves the hand on his dial until it is set at the words "train on line," the hand at station 2 is automatically moved into the same position by means of an electric circuit, so that the operator at station 2 not only receives notice by means of the electric bells that the train has entered the block, but by the movement of his indicator as well. When the train passes out of the block and is between stations 2 and 3, as soon as No. 2 notifies No. 1, he moves his indicator hand to the words "line closed," when the hand at No. 1 is automatically moved to the same position.

In what is shown as the automanual system in Great Britain, the signal man at station 2 controls the mechanism at No. 1, the operator at No. 3 controls the mechanism at No. 2, and so on along the line. When a train is to enter the first block the operator at No. 1 notifies station 2 by the electric bell. When No. 2 receives this announcement and the block is clear, he sets the signal at station 1 at safety. As soon as the train enters the block the signal at No. 1 is automatically set at the danger point, but the operator at No. 1 is obliged to pull a hand lever which connects with the signal and locks it in the position of danger. It cannot be moved except by the operator at station 2, and remains in this position, not only after the train has passed out of the block, but until another is ready to enter, when it is released and set at safety in the manner described.

On the majority of the more extensive railways in the United Kingdom the day signals are of the semaphore order, and usually each station is provided with three,—the advance, the distant, and the home signal. All are, of course, set at the danger or the safety point simultaneously, and if one is in a different position from another the engineer must come to a full stop until he ascertains which signal is correct. The advance signal is at least 500 feet from the station, and the distant semaphore is half way between the advance signal and the station. The blades of the semaphores are controlled by means of wires running through conduits and passing over pulleys at curves. They are moved by means of hand levers, electric power directly applied, or by compressed air cylinders actuated by the electric current. When a track circuit is employed, as in the controlled manual system, a battery is placed at one end of the block and the relay and signal

are at the other end. The relay controls a local circuit operating an electromagnet. The electromagnet, or the air valves of the pneumatic system, if this is employed, actuate the signal directly.

The use of the train staff or train tablet is very extensive on the single-track lines of Great Britain, and has the credit of effectually safeguarding lines of this class. At each block station is installed a machine electrically operated, which contains a series of small rods or of metal tablets about three inches in diameter. These are so arranged in the machine that one only can be released by the operator at the station beyond so that it can be taken from the machine. When released it is in such a position that a movable arm or crane attached to the side of the engine cab will grasp it as the train passes the staff machine. This device is moved by a lever from the interior of the cab, and is somewhat similar to that employed for taking up mail bags when the train passes a mail station without stopping. At the end of the block the crane places the tablet or staff in the machine without checking speed.

In explaining the method of controlling train service by the staff, we will suppose that a train is to enter the block between stations 1 and 2. The operator at No. 1 presses a button or key which rings a bell at No. 2. This is a signal to release a staff if all the trains are out of the block. The operator at station 2 answers the signal, then presses a key governing what is called the current indicator, which announces to the operator at station 1 that the right-of-way is open. No. 1 moves a spindle connecting with the armature of an electromagnet, which releases what is called the lock wheel of the apparatus. By turning a handle the staff is in a position to be withdrawn. When the lock wheel is turned it acts upon the circuit controller which reverses the battery at station 1, causing the armature to return to its original position. At the same time the indicator is moved to what is known as the "staff-out" position. This is also indicated simultaneously at station 2, and the operator at 2 releases his key. The staff is then ready for delivery to the train.

When it is returned to station 2, the signal man in this station moves the lever of the lock wheel in his machine to the right, which fastens the staff in place. He then rings the bell at station 1 notifying the operator there that the train has passed out of the block. The same current also actuates the indicator at station 1 and it is moved from the position at "staff-out" to "staff-in." When it is so set the operator at No. 1 must notify No. 2 before the machine at station 1 can be adjusted to deliver a staff to the following train.

The speed at which a train is running, as well as the grade of the track and the weather conditions, are very essential in the successful operation of the block system as applied to American railways. In America the lines thus protected are subdivided into blocks, some of which are actually less than a mile in length. It is obvious that on railways where the train service is frequent the block stations must be placed as closely together as possible in order to avoid delay and yet protect the service. Where the block is but a mile in length and a train occupies it, unless the one following is running at reduced speed, it may overrun the block.

It must be remembered that freight trains these days may be nearly a mile long if made up of empty cars, and that the short block requires great caution in running passenger trains. An express train running on a level plane or down grade may attain a speed of from 60 to 80 miles an hour in order to maintain its schedule of 45 or 50 miles an hour, the engineer taking advantage of the alignment of the road.

It has been demonstrated beyond question that on a level track with dry rails it is impossible to stop a train running at the rate of 60 miles an hour within 1200 feet. Even then the

full force of the air brakes must be applied at once, and the engineer must take the chances of seriously injuring passengers by the shock. Where the brakes are applied gradually, at least 2000 feet will be covered before the train reaches a full stop. If running at a 90-mile rate, 3000 feet or over a half mile is required to bring it to a halt under the same conditions. On a down grade or when the rails are wet and slippery, it is obviously impossible to check the momentum within these distances, and unless sufficient space intervenes between the two trains a collision is inevitable even with a block system in use. This is a fact which must be taken into consideration.

In a wide-spread discussion of this subject the critics of transportation service have arraigned everyone connected with it from president down to track walker. The employees especially have been accused of negligence and indifference, and surprising as it may seem, a few of the railroad officials themselves have made wholesale charges of this character. It may also be said in passing that some of the statements which have been published show astonishing ignorance on the part of the authors.

The writer believes that there has never been a period in the railroad history of the United States when the employees, considered as a whole, have been more attentive to their work or have displayed more efficiency considering the labour required of them. Officials who come in actual contact with the men along the right-of-way, at the stations and directly connected with the train service, will verify this claim if they are disposed to be impartial.

It is true that many of the accidents have been traced to what the juries are fond of terming the "culpable negligence" of the engineer, the flagman or some other individual, but considering the circumstances it is only strange that disasters of this kind have not been far more frequent. Where the engineer does not pay the penalty of error with his life, as is too frequently the case, in the majority of instances he is blamed for the collision. Next in line comes the operator at the block station if the system is equipped with such signals, or the operator at the point where the train was to be held, if the ordinary method of train dispatching by telegraph is in vogue.

The engineer gets the brunt of the blame for the casualties resulting from collisions, but is it just to make him responsible considering what is expected of him to earn his salary? To the novice in railroading the engineer's work seems to consist chiefly of looking out of the cab window, reversing his lever and "opening the throttle." Truly, he does look out of the window when he is not obliged to look at a score of other things inside the cab. From the time he lets the steam enter the cylinders every fraction of a minute during the run should be occupied if he is attending properly to his duties, as they are associated both with the mechanism of the locomotive and the roadway.

The throttle, reverse lever and brake valve are three things that are constantly under his hand and eye, as by these he controls the movement of his train. The injector by which he feeds water to the boiler requires constant attention in connection with the water gauge which shows the level of water in the boiler. When an engine is driven to its greatest capacity, as is usually the case, the water level has to be noted very closely, as it is frequently necessary to "nurse" the engine to keep up the required steam pressure and make time. This involves cutting down the water supply or shutting off the injector entirely on heavy grades and feeding a little more water than really is needed on easy grades.

The injector is also shut off completely when pulling out of a station so as to give the exhaust a chance to "liven up" the fire before water is put into the boiler, thus preventing loss of steam. In connection with this manipulation of the injector the engineer must watch the steam gauge closely.

Then the eye must often be on the air gauge to see that there is always the required pressure of air for braking. The lubricators which feed oil to the cylinders and steam chests and also the air pump require frequent attention.

The roadway division of the engineer's duties include a knowledge of every crossing, every bridge and culvert of importance, all grades of any considerable percentage, as well as curves, weak spots where it may be necessary to run slowly over a soft roadbed and where there are pieces of new construction, also signals. While the fireman sounds the bell if the company does not provide an automatic bell ringer, the approach to every crossing must be announced by the familiar four whistles. Other whistle signals must be given when the train breaks in two, sometimes on approaching a town when it is necessary to move the train backwards and for other purposes. On the majority of railroads approaches to towns are indicated by posts marked with such signs as "run slow," whistle" or "ring." The limits of freight yards are generally indicated in the same way. All of these posts must be as well known to the engineer as are his valves and levers. In short, he must become a human encyclopædia in the mileage covered by his run, since he may be obliged to go over it by night as well as by day.

Consider for a moment what the engineer must attend to on one of the larger double-track systems. If he is running an express train, in order to maintain schedule time he must develop a speed ranging from 45 to 75 miles an hour. To properly control the various mechanisms should be sufficient to require his undivided attention, but in addition he is expected to keep a continual lookout for the block signals which he may pass every 5 or 10 minutes if there are any, and for all grade crossings as well as road signs.

The experienced engineer is so familiar with the location of the bridges, curves, etc., that he "slows down" on approaching them more by intuition than by observation, but running at even 40 miles an hour it is remarkable indeed if he does not occasionally fail to observe the warning of the semaphore, especially on a foggy day or a dark night where the colour of the lamp may not be visible 300 feet from the cab.

True, the fireman is supposed to assist the engineer by also keeping a look-out, but he is not responsible in case of accident, and if he should neglect to observe an indication of danger the blame generally falls upon his superior. Since the construction of express engines with boilers dividing the cab into two parts practically shuts off the engineer and fireman from each other during the entire run, the duties of the former become even more arduous, and with the increase in engine power and size, there has also been an increase in the number of appliances to be controlled from the cab. The establishment of the block system means also more signals to observe. In spite of the progress which has been made in railroad transportation service, nothing has been done to relieve the engineer of work, but on the other hand his burdens have been increased.

The engineer's hours of service may range as high as 12 or 15 in 24. This has been verified by testimony in investigations of railroad disasters, while the records of the Interstate Commerce Commission contain several instances where the man in the cab has been obliged to be on continuous duty for actually 20 and 24 hours, although these are, fortunately, isolated examples.

In studying the methods of train service on railways in America one fact stands out conspicuously,—the eye is depended upon almost absolutely. Even in the operation of the train staff the safety of the train rests with the vision and memory of the engineer. Thus far no plan has been adopted which employs the sense of hearing, except the train despatcher system which has proven so dangerous

and defective. Consequently there is good ground for the argument that the engine crew of an express train should include not only the engineer and fireman, but a lookout man whose entire duty would be to observe the roadway. It has been suggested that he should be stationed in a compartment above the pilot where he could see not merely the half visible from the cab window, but all of the way, communicating with the engineer by telephone or electric bells. Thus the latter would be left to perform his legitimate duties which so frequently distract his attention from observing signals.

The term "block signals" as applied to most of the systems is really a misnomer despite their undoubted value as a protection, for they do not make it impossible for one train to collide with another. While on a clear day or a clear night the chances for danger are undoubtedly reduced to a minimum where the system is properly operated, there are atmospheric conditions which frequently render signals invisible, especially in sections of the country adjacent to the seacoast where fog is more or less prevalent.

If the signal cannot be observed until the locomotive is within a few feet of the block station, it may be impossible to "slow up" the train until it has crashed into the one preceding it. A recent illustration of this was given by a disaster in the suburbs of Paris, where the Lille express struck the rear end of the Boulogne express just as the latter was pulling out of a block section. One car was practically demolished, 13 passengers were killed and a large number injured. The investigation disclosed the fact that the engine crew of the Lille express could not perceive the danger signal by reason of the fog until too late to prevent striking the other train. The railroad on which the disaster occurred was provided with one of the latest designs of controlled manual signals. Several collisions have occurred on railways in America thus protected, but due to the same cause.

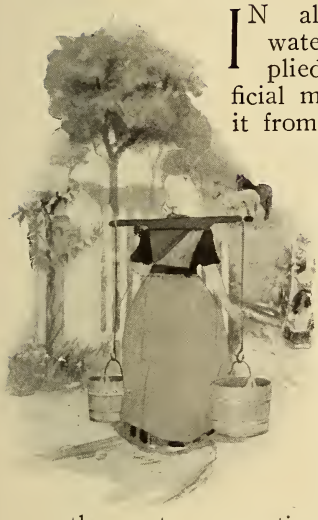
There appears to be no reason why block systems cannot be installed and so arranged that by merely converting each block into a switch it would be absolutely impossible for a train to enter a block occupied. It is unnecessary to say that switches which are actuated entirely by the movement of trains are now in common use in yards. When a train enters upon a switch and the last car has passed from the main line, it is opened or separated so that a train following would be derailed in attempting to enter the siding. Thus the terminals of a block could readily be disconnected to be closed by the station operator or automatic equipment at the moment the block was clear. Such a system could be operated as rapidly if not more rapidly than the methods now in vogue.

On even a 100-mile railway, however, such equipment would mean a heavy expense, and on a thousand miles a proportionately greater expense. And so it is that one of the principal reasons for the loss of life on American railroads is the financial inability or unwillingness of their owners to adopt better means for human protection. But a remedy at once suggests itself,—legislation. Law compelled the almost universal application of the air brake and the automatic coupler. When public opinion reaches such a point that it imperatively demands a better system of train control, then we shall have laws like those of Great Britain, which absolutely require corporations to employ some form of block division.

THE WATER SUPPLY OF COUNTRY BUILDINGS

By Wm. Paul Gerhard, C. E., M. Am. Soc. M. E.

PART II.—CONSIDERATION OF DETAILS



IN all cases where water cannot be supplied by gravity, artificial means for raising it from a lower to the desired higher level must be provided. This leads to a more detailed consideration of the usual types of water pumping machinery. All such machinery consists essentially of two parts,—namely, the pump and the motor operating it. There are numerous varieties of apparatus for raising water from which to choose, but in a brief article only the chief kinds can be mentioned. In actual practice the choice of suitable pumping machinery is usually restricted to a few types of the peculiar conditions governing each problem.

First, as regards the motor. We must distinguish between motors operated by natural and those using artificially created forces. The natural forces applied for pumping water comprise the muscular or hand-power of men, the power of animals, such as horses, oxen or donkeys, the force of the wind, the force of water in motion, and the power of falling water. Artificial motive powers embrace all motors using fuel in some form of an engine in which the heat is converted into power. The fuel may be either coal, wood, gas, oil, naphtha or gasoline, and the power derived therefrom may be either steam, compressed air, hot air, or electric power.

Water may be raised by other and simpler devices than pumps, such as machines with scoops, pails or boxes, machines with moving water channels, or finally those in which water is raised in fixed conduits by chains or other means. Many of these devices are of a primitive kind, have gone almost out of use, and are only historically interesting. We may safely pass them over to discuss the more universally used machines in which water is raised in fixed channels by means of pistons, plungers, impellers, worm gears, or by steam, water or compressed air jets. Such machines are designated as pumps.

Pumps may be either lift or lift and force pumps, piston or plunger pumps, single or double-acting, rotary or reciprocating, and finally simplex, duplex or triplex pumps. In the last named pumps all three pistons or plungers are mounted on the same shaft, with the cranks set at equal angles to each other, and thereby give a much steadier and more uniform discharge. We may also distinguish between vertical and horizontal, and between stationary and portable forms of pumps. Water lifting apparatus is also constructed either for surface supplies or for deep wells.

As regards the connection between the motor and the pump, the power in many machines is applied directly, as in the direct-acting steam pump and in the direct-connected electric pump, both motor and pump being mounted on the same shaft. In other cases the power is applied indirectly by means of gearing, belting, noiseless chains or

crankshaft movements, and the pumps are then designated as power pumps.

To each kind of pumping engine belong certain advantages and disadvantages. In every case the conditions under which the pumping engine is to do work must be carefully looked into before a selection is made. One should always consider, not only the first cost of the pump, but also its running expenses, cost of fuel, repairs and maintenance.

Hand pumping is uncertain and unsatisfactory; it can be applied only to small volumes of water and to small lifts. Lift or force pumps operated by hand are useful only in the case of farm buildings or cottages of moderate size. Their only advantage lies in the cheapness of the labour. In countries where animals are cheap, these, too, are used to some extent in operating water lifting apparatus, but as a rule such use of farm animals does not commend itself. The water to be used on farms or in farm buildings is more often lifted by the force of the wind, with windmills, or by the force of water in motion, with hydraulic rams. As will be pointed out, both are very economical, as the motive force costs nothing. If neither of these is available, some form of fuel engine must necessarily be used.

Wind as a motive power is utilised extensively for the pumping of water, and in numerous cases, when properly installed, windmills provide a satisfactory water supply at a minimum expense. This motive force is both convenient and economical, but it is also somewhat uncertain, for the source of power is beyond human control. The wind does not always blow with sufficient force to move a windmill, and a velocity of the wind of from 4 to 8 miles an hour is not sufficient. The best results are obtained with wind velocities of from 12 to 16 miles an

FIG. 15.—THE TANK MAY BE PLACED BELOW THE WINDMILL ON THE SAME TOWER

FIG. 16.—OR IT MAY BE ERECTED ELSEWHERE AT A CONVENIENT ELEVATION

INSTALLED BY A. J. CORCORAN, JERSEY CITY, N. J.

FIG. 17.—TWO HYDRAULIC RAMS SUPPLYING 100,000 GALLONS OF WATER DAILY TO THE TOWN OF BRISTOL, VERMONT, U. S. A. THE RESERVOIR IS 200 FEET ABOVE THE RAMS. THE LATTER WERE MADE BY THE RIFE ENGINEERING CO., NEW YORK

hour. Windmills require skill and judgment in their application and erection, and a preliminary careful study of the topography of the grounds. It is essential to erect them in a rather exposed elevation, on high ground, so that the wheel may receive the full force of the wind. Even when so situated, a windmill will work only a part of the time, an average of eight hours per day, and to allow for the unavoidable periods of calm, it is necessary to provide ample storage capacity in the tanks.

A complete windmill pumping plant comprises a tower for the wheel, a pump with piping, and a storage tank. The tank may be placed below the windmill on the same tower as in Fig. 15, or it may be supported elsewhere as in Fig. 16. The tower must be so placed as to secure the best exposure of the wheel; too low towers frequently lead to failure. The wheel must be carefully mounted and the tower must be substantial and strong, supported on brick or stone piers. The corner posts should be anchored to the piers

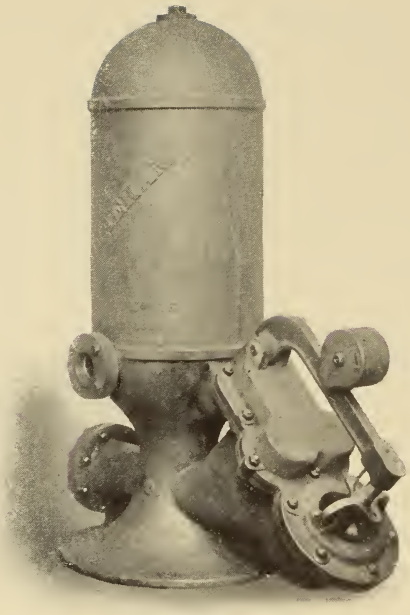


FIG. 18.—AN IMPROVED FORM OF HYDRAULIC RAM MADE BY THE DEMING CO., SALEM, OHIO, U. S. A.

by means of strong wrought iron bolts; the tower should be framed and rodded, and not, like the cheaper ones, merely spiked together. Both wooden and steel towers are used, and there are wooden as well as steel wheels. The wheels should be built with a view of withstanding hard storms. The pumping apparatus should be of the simplest kind in order to be managed by the farm hands. Tank, pump, and piping must be frostproofed, except in cases where the supply is designed for summer use only. The wheel is usually provided with self-regulating attachments. Sometimes a windmill is used for other purposes in addition to the pumping of water, such as the running of dynamos for generating electricity.

The force of running water is utilised in hydraulic rams for the lifting of water to a height greater than that of the source of supply for the ram. Wherever there is a volume of flowing water ample at all times to run a ram, these self-acting machines are among the most useful, cheap, economical, and satisfactory motors for lifting water. They require but very little attendance and hardly any care or expense in maintenance. They

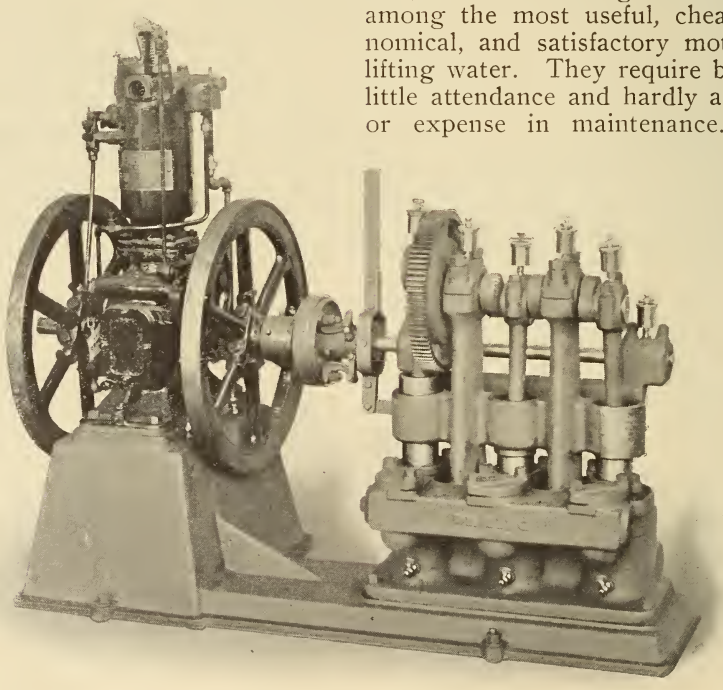


FIG. 19.—A DEMING TRIPLEX HOUSE SUPPLY PUMP, DRIVEN BY A GAS ENGINE, MADE BY MESSRS. FAIRBANKS, MORSE & CO., CHICAGO

operate automatically and occupy a field entirely by themselves.

The ram is set up in an underground pit located at a suitable distance below the source of supply. The existing conditions must be first carefully studied out, for they govern the location of the ram, its size, and the dimensions of the drive and the discharge pipes. Hydraulic rams are made in many sizes and capacities, the smallest supplying about 500 gallons, and the largest up to 500-000 gallons in 24 hours.

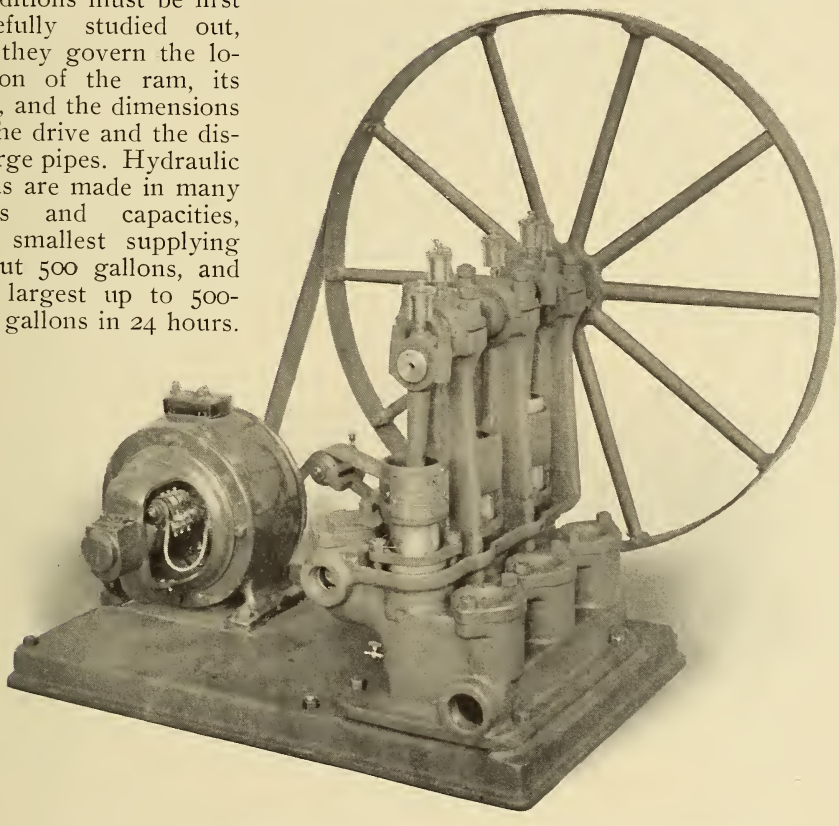


FIG. 20.—A DEMING TRIPLEX PUMP WITH MOTOR CONNECTED BY BELT AND IDLER

They will elevate water from five to several hundred feet. Sometimes several rams are set to work in batteries, with separate drive pipes, but with a common discharge pipe. The improved forms of rams, or hydraulic engines, like those shown in Figs. 17 and 18, are much more efficient than the old forms and often develop an efficiency of from 70 to 80 per cent. These types have adjustable valve mechanisms which can be easily regulated so as to secure the best working conditions. Double-acting rams are also manufactured which use an impure source of water to pump a pure supply.

If running water exists in sufficient quantity, water may be pumped by utilising the power of falling water, either in water wheels or in turbines. Hydraulic power is economical because there are practically no running expenses; it is easily managed, as the machines require only occasional looking after. The drawback is that, in many situations, water power is unreliable and at times insufficient.

Water wheels always turn on a horizontal axis, whereas the turbines are usually mounted on a vertical axis. The different types of water wheels, such as the overshot wheel, used where the fall in a stream is considerable, and in which the water acts both by its weight and by the force of the impact; the undershot wheel, used where there is only a small fall, and in which the water acts largely by im-

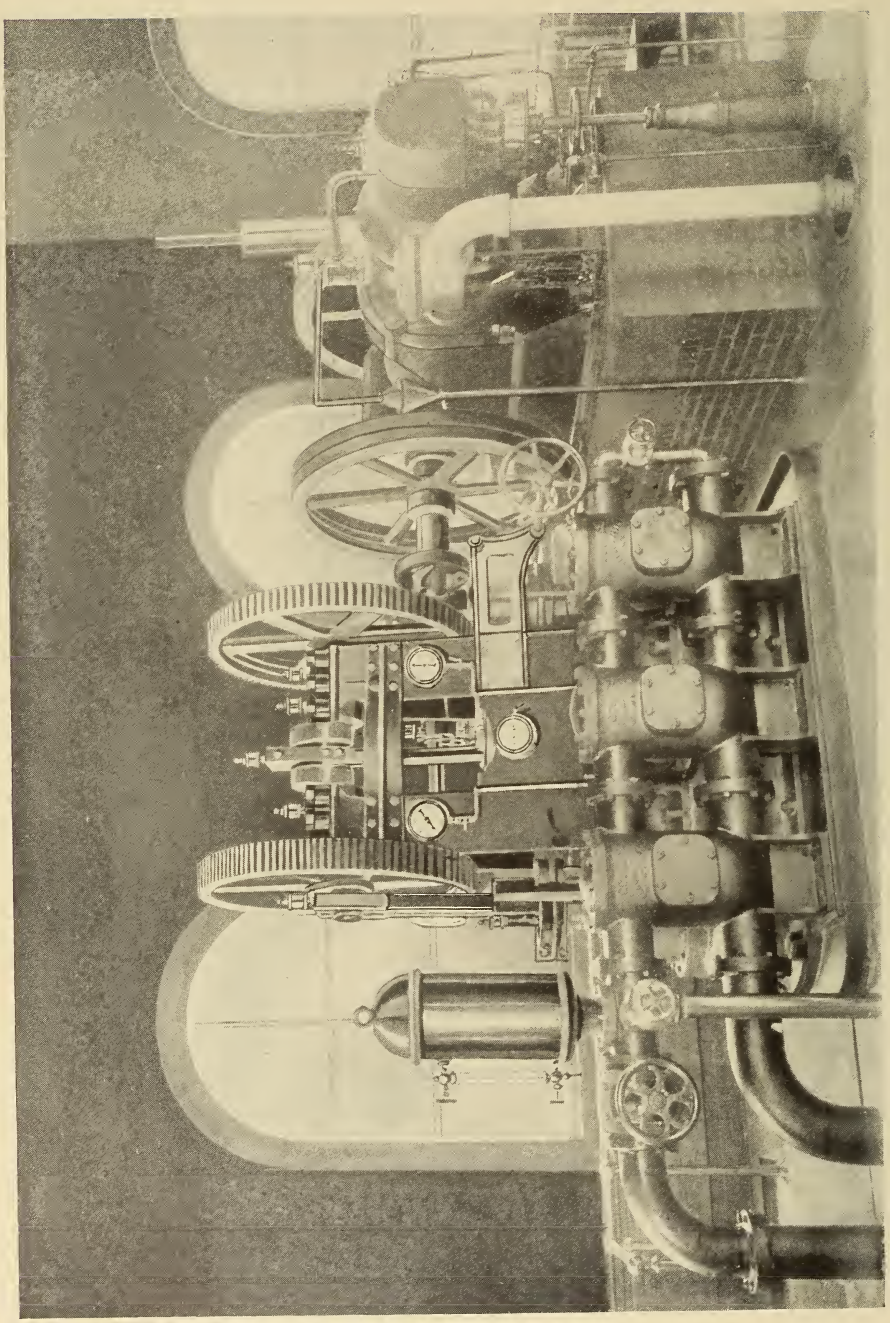


FIG. 21.—A 20-H. P. HORNSBY-AKROYD OIL ENGINE INSTALLED AT THE WINCHESTER, MASS., WATER WORKS, DRIVING PUMPS MADE BY THE GOULDS MFG. CO., SENECA FALLS, NEW YORK. THE HORNSBY-AKROYD ENGINE IS MADE IN ENGLAND BY MESSRS. R. HORNSBY & SONS, LTD., OF GRANTHAM, AND IN AMERICA BY THE DE LA VERGNE MACHINE CO., OF NEW YORK

pulse; the breast wheel, which in type stands between the two mentioned; and finally the turbines, which are preferred where there is a considerable fall of water, can all be adapted to the running of pumping machinery. The efficiencies of these motors are high, particularly in the case of turbines, in which they are often as much as 75 per cent.

Hydraulic motors, in which the water is used in driving a piston in a cylinder in the same way as steam or compressed air operates, are not used for the pumping of water for country houses, but in the operation of large water works such engines are occasionally met with.

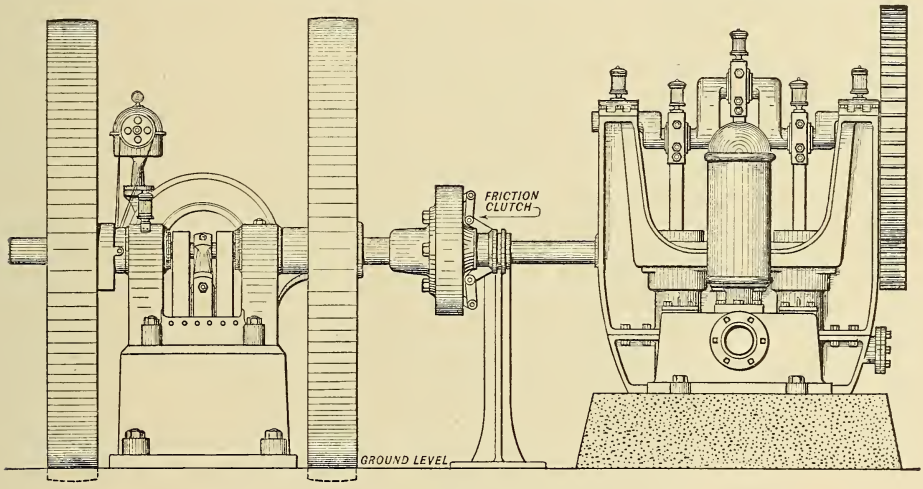


FIG. 22.—END ELEVATION OF A HORNSBY-AKROYD OIL ENGINE DRIVING A TRIPLEX PUMP

Among fuel engines adapted for pumping water, the first to be mentioned will be the gas engine. In this machine the motive force is produced by the expansion of a mixture of gas with air. This when ignited explodes, and the force generated is utilised in moving a piston operating the pump.

The essential requirements for a gas engine are a supply of illuminating gas or else a special gas generating plant, and also a supply of water which is necessary to constantly cool the engine by means of a water jacket. One of the advantages of gas engines is that they can be started at full speed almost as soon as the gas is lighted. Once started, they require but very little attendance. There is no fire to be kept fed, no nuisance from smoke and ashes. Gas engines are economical machines for pumping water. The drawbacks are the disagreeable odours arising from the burning of gas, or from small leaks, and the noise of the exhaust. Gas pumping engines for domestic use are built in sizes ranging from 0.5 to 16 horse-power. The gas engine has been developed considerably in other directions during recent years, and large gas engines developing 1000 horse-power and more are being successfully built and installed in place of steam engines. They use for fuel the waste gases from coke furnaces or else require special fuel gas plants. Gas engines of the form shown in Fig. 19 have been frequently used in pumping water for isolated houses, but in recent years they are being replaced more and more by oil engines.

Oil engines for pumping water are similar to gas engines, except that the former do not require a gas supply or a gas producing plant, for oil engines use an independent fuel, such as crude oil or kerosene, which is readily supplied and brought to the engine. The oil is vapourised by heat

and the resulting vapour is ignited, either by an electric spark or by other means. The resulting compression of air furnishes the motive power.

The oil engine resembles the gas engine in so far as it requires no boiler and no skilled engineer to run it. It is simple in construction, reliable and efficient in action, durable in service, and economical to run. It costs but little to operate, can be run intermittently, and is quickly available in case of emergency. Oil engines are built in sizes from 1 to about 20 horsepower; the smaller sizes are more efficient than steam pumps, and compared with gas engines they are somewhat cheaper to run. No danger is connected with their use, and any ordinary intelligent labourer can start and run them.

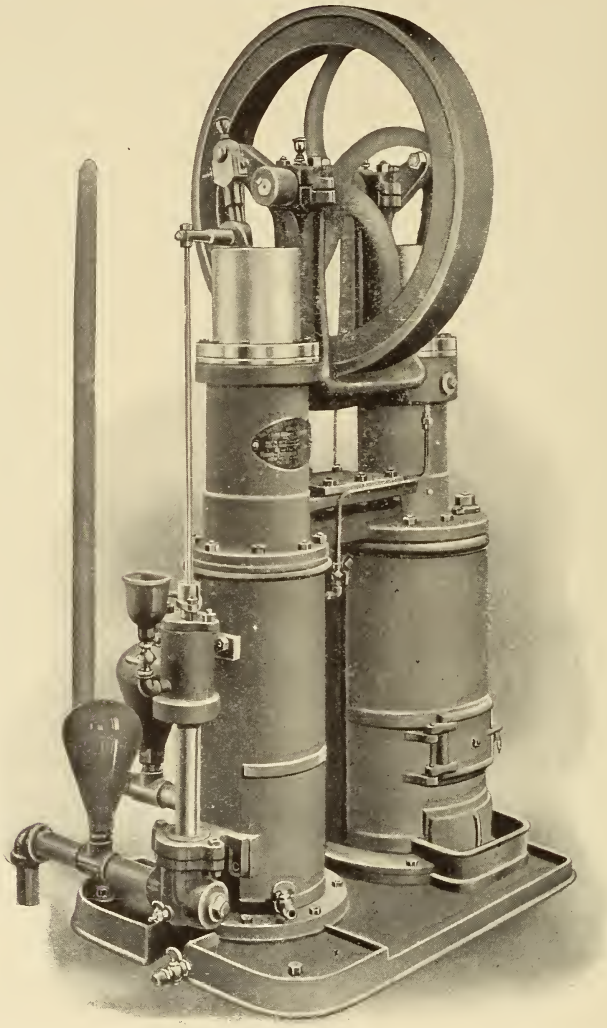


FIG. 23.—A RIDER HOT AIR PUMPING ENGINE, ARRANGED FOR USING EITHER GAS, OIL OR COAL AS FUEL. MADE BY THE RIDER-ERICSSON ENGINE CO., NEW YORK

Great progress has been made during recent years in the design of oil engines, one of the well-known forms of which is shown in Figs. 21 and 22. The oil engine is one of the more mod-

ern kinds of motors for the raising of water; it is a favourite, particularly in portable form, and in localities where the water is so hard as to be unsuitable for use in steam boilers. Its only drawbacks are the smell of the oil and the noise in operation.

In gasoline pumping engines, power is obtained from the explosion of a mixture of air and the vapour of gasoline. They resemble in many respects the gas engines, but the latter and the oil engines are much safer, for gasoline is a highly volatile liquid. It is well known that from the fire underwriters' point of view, all mechanical appliances using the vapour of gasoline are considered to be highly dangerous.

Another type of engine for pumping water which has been used extensively for many years, and which has proven quite successful and economical in use, is the hot air or caloric pumping engine. The operating force is derived from the expansion of atmospheric air in a cylinder by the heat of combustion. The caloric engines are manufactured in various forms, and the fuel which they burn is either coal, coke, wood, gas, oil or gasoline. Two forms of such engines are shown in Figs. 23 and 24.

One of the reasons for their having proved successful is the fact that they can be run and attended by unskilled persons, and that after being started they require no further supervision beyond an occasional oiling of the working parts. No danger is attached to their operation. Hot air engines require a supply of circulating water for the cooling of the air cylinder. Compared with oil engines they have the slight drawback that they cannot be so quickly stopped when running.

Hot air engines are built in several sizes, with capacities ranging from 2 to 25 gallons per minute. They force water up to a height of from 50 to 150 feet. The power developed is small, ranging from $\frac{1}{4}$ to 1 horse-power. The machines are simple in construction and tolerably free from noise in action. While they have given excellent service in numerous cases, they have the disadvantage that the working parts are liable to require frequent repairs.

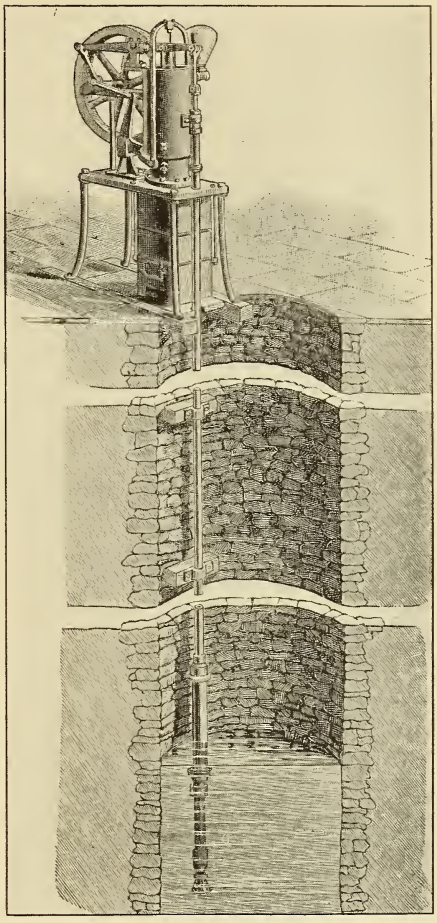


FIG. 24.—ERICSSON HOT AIR PUMPING ENGINE, MADE BY THE RIDER-ERICSSON ENGINE CO., NEW YORK, APPLIED TO PUMPING FROM DEEP WELLS

Steam pumps are not often used for the supply of water to country houses, but where steam is already available, as in the case of large institutions equipped with a steam boiler plant, the use of a steam pump should at least be considered. It is quite usual in such cases to use the well-known forms of duplex direct-acting non-condensing pumps, and sometimes the compound tandem simplex or duplex pumps. Condensing steam pumps and high-duty pumping engines are

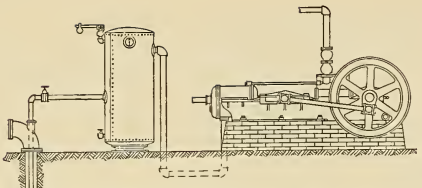


FIG. 25.—AN AIR LIFT PUMP OUTFIT

considered only in exceptional cases, particularly where a high economy in operation is expected.

Where the power required exceeds 15 to 20 horse-power, steam pumps are economical in use. Among the disadvantages are the heavy first outlay for the pumps, the constant expenditure for fuel generating steam, and the continuous skilled attendance required.

For an isolated pumping plant, a combination of direct-acting steam pump and vertical boiler is much used, which commends itself because of the compactness of the apparatus.

A low-pressure steam and vacuum pump is also manufactured; it is adapted for use in residences and has been moderately successful.

Water has in recent years been pumped by means of compressed air. A form of apparatus, usually designated as an air lift pump, is much used because of its simplicity and efficiency, particularly in the case of deep wells. Such air lift devices afford an opportunity for increasing the yield of wells; from a sanitary point of view this method of pumping recommends itself because of the beneficial effect derived from the aeration of the water. From a mechanical standpoint the air lift device is preferable for deep wells because it does away with any working parts, such as the pump barrels lowered into the well. It dispenses with pumps entirely and all the machinery is above ground. The air

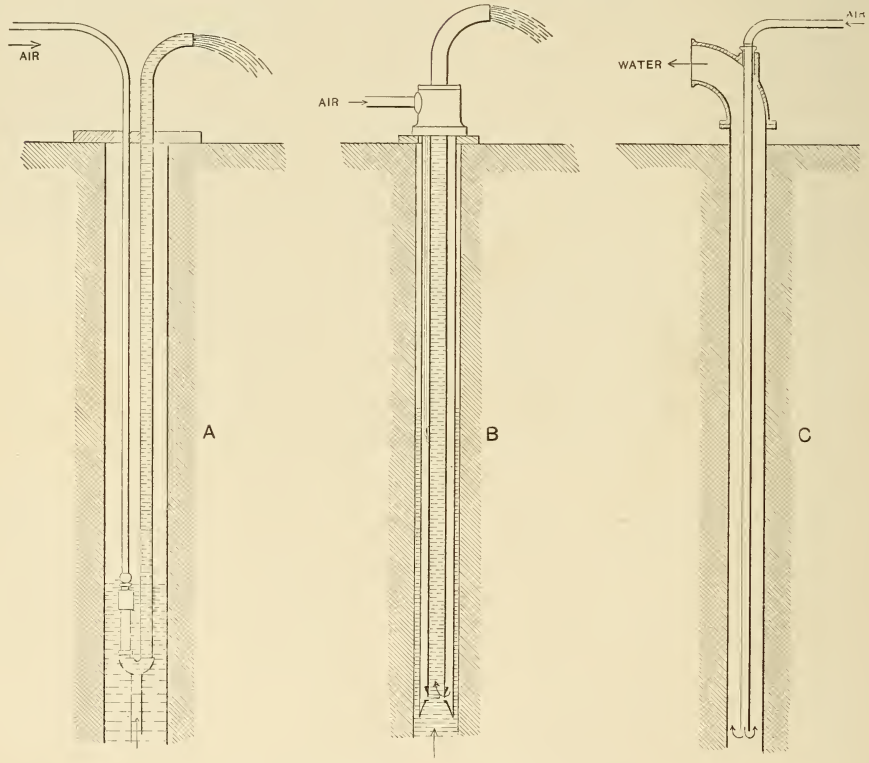


FIG. 26.—SEVERAL FORMS OF AIR LIFT PUMPS

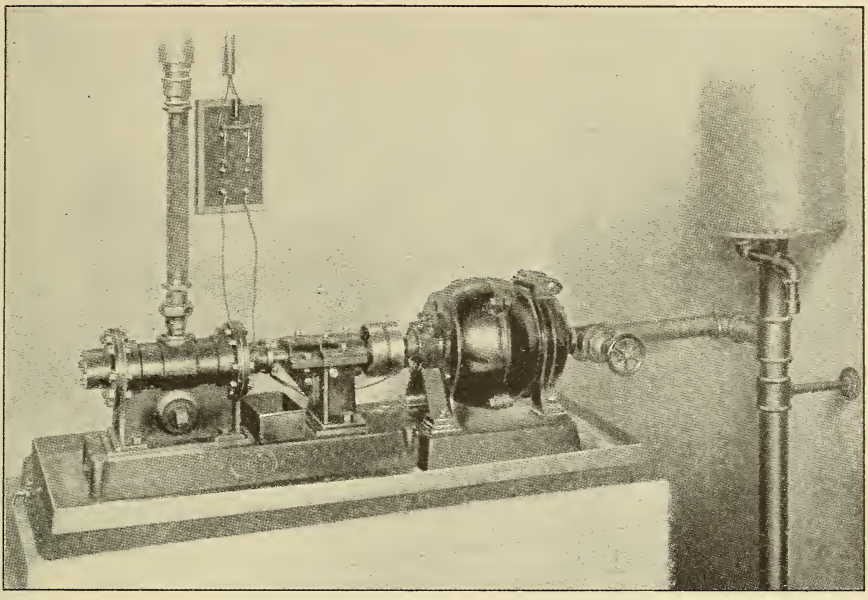


FIG. 27.—AN ELECTRICALLY-DRIVEN SCREW PUMP WITH MOTOR AND PUMP ON THE SAME SHAFT AND BEDPLATE, MADE BY WM. E. QUIMBY, INC., NEW YORK

compressor required may be run by an oil engine, an electric motor, a water wheel or turbine, or by steam, as in Fig. 25.

There are several forms of air lift apparatus:—one is shown at *A*, Fig. 26, in which the air and water pipes are placed alongside of each other in the well casing and connected at the bottom; another shown at *B*, in which a water delivery pipe is placed into the well and in which the air passes down through the annular space between the well casing and the delivery pipe; still another, shown at *C*, Fig. 26, in which the well pipe is used as a water delivery pipe and which has an air pipe put down into the well, the air being made to escape at the bottom by means of a special device.

The air lift process of pumping water has been quite successful in recent years, and for the future a more frequent application of the method seems to be assured. Compressed air may also be used, either at a constant pressure or else expansively in direct-acting pumps, but this is not a usual form of pumping apparatus.

In recent years electric house-pumps have been used extensively, and this notwithstanding the fact that the employment of the electric current is still quite expensive.

Electric power has become popular and successful because of its many advantages. Electric pumps are compact, extremely convenient and clean in operation, occupy but little floor space, are generally quite noiseless, create no smell, heat or dirt, and require no handling of fuel or the removal of the waste products of combustion. Electric house-pumps can be run without much skilled attendance and require a minimum of care and attention. They can be run intermittently or be fitted up so as to operate automatically. The force operating them is produced by means of a motor, which converts the electric current into power. The motor is either connected directly with the pump, or else operates it by means of gearing, belting, noiseless chains or worm gears.

An incidental advantage of electric pumps is that the power may be transmitted a long distance, and that the

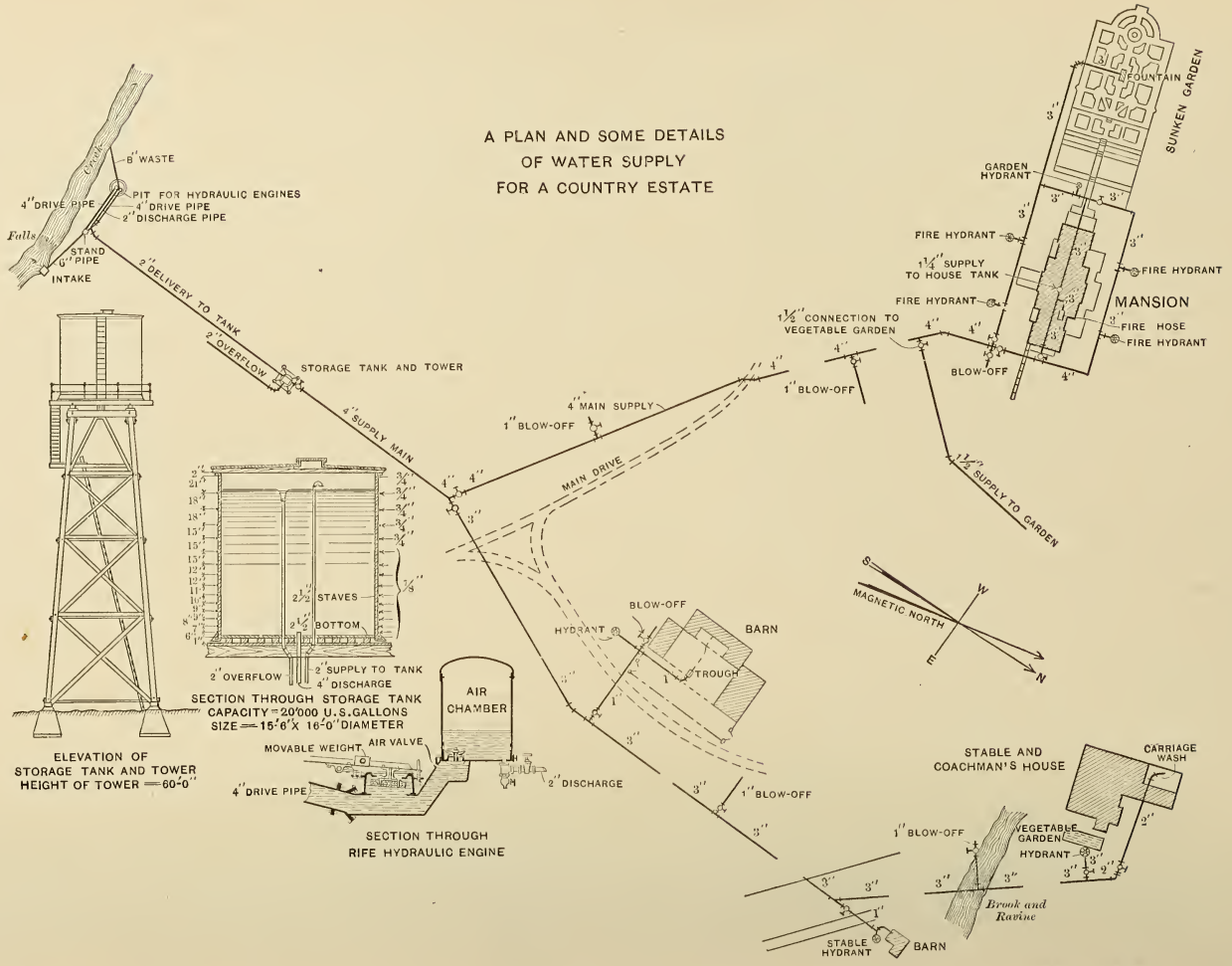


FIG. 28.—THE WATER SUPPLY IS DERIVED FROM A BROOK AND IS PUMPED TO A TANK BY TWO RIFE HYDRAULIC RAMS

pumps may be operated at a distance from the point of control.

A popular form of electric house-pump is shown in Fig. 27, and consists of a direct-connected screw pump, with motor and pump mounted on the same shaft and bedplate. A belt-driven triplex piston, electric house-pump, designed to run at a moderate speed is shown in Fig. 20.

A triplex electric house-pump operated by worm-gearing, rendered noiseless by running in a chamber filled with oil, is shown in Fig. 30.

Centrifugal pumps could not until quite recently be used to any large extent for the pumping of water because their power was confined to moderate lifts, not exceeding about 20 feet. A new modification of the centrifugal pump, shown in Fig. 29, differs in this respect, as it is designed particularly for high lifts up to several hundred feet. In this new form of centrifugal pump the apparatus is so arranged that the water is pumped in several stages, and the pump is designated as a multi-stage turbine pump. The different impellers are mounted on a single shaft and the water passes through the impeller chambers in succession; in this way the usually moderate lift is multiplied several times.

Deep-well pumping machinery requires a plunger of suitable size in order to keep the speed of the piston within working limits. This is one reason why deep wells require pipes of larger diameter than is necessary with the ordinary driven well. For deep-well pumping, a single acting ball-valve cylinder pump is the best because of its simple construction. Such apparatus is apt to give considerable trouble when breaks occur in the working parts which are lowered into the well to a great depth. The entire machinery requires to be well designed and strongly constructed because of the great strains on the working parts caused by sudden stopping or starting of the machinery.

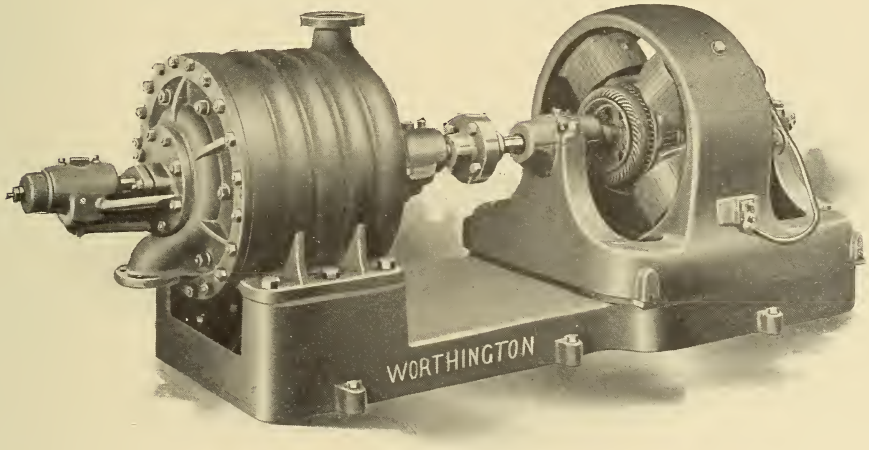


FIG. 29.—A FIVE-STAGE WORTHINGTON TURBINE PUMP FOR HIGH LIFTS

Whatever the style or type of pumping engine selected, it must be borne in mind that the capacity of the pump should be such as to furnish the maximum daily amount required in a few hours. In the case of country houses, continuous pumping is generally out of the question. This statement applies to all fuel pumping engines, and only the hydraulic ram, the various forms of water wheels, and the windmill form exceptions to the rule.

An example of a complete system of water supply, including fire protec-

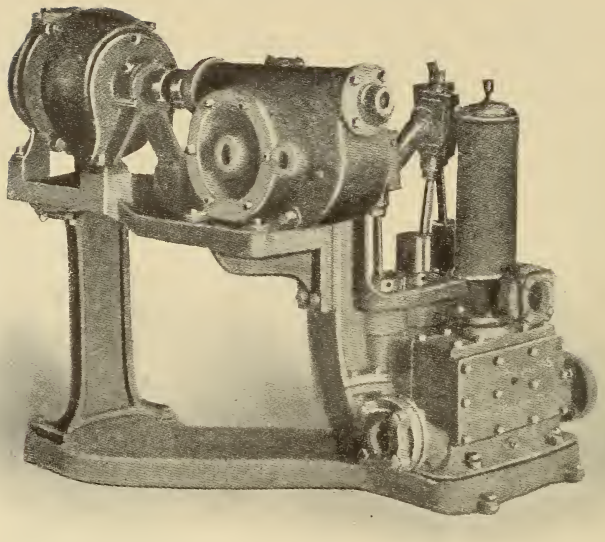


FIG. 30. A TRIPLEX ELECTRIC HOUSE-PUMP. MADE BY W. & B. DOUGLAS, NEW YORK

tion, for a country residence, is given in Fig. 28. In this case the house supply is derived from a brook which runs at all times a fairly large stream of water. The water is pumped to the outside tank shown in the illustration by two Rife hydraulic engines operated by means of two 4-inch drive pipes and having one 2-inch discharge pipe. The tank is a wooden one of 20,000 gallons capacity, supported on an open wooden tower, the height of which is approximately 60 feet. The falling main from the tank is a 4-inch pipe, and the main supply conduit is run 4 inches in size to the mansion, around which is provided a distribution system consisting of 3-inch pipes with 3-inch branches to four fire hydrants. The mains were purposely made large because the available tank pressure was not very high, the ground where the tank tower was erected being only a few feet higher than the site for the mansion.

An inside fire stand pipe is also supplied from the outside service under direct pressure, while the house supply for domestic use is obtained from an attic tank fed by a branch from the 4-inch main. A 3-inch pipe is branched off from the main and is carried past the sheep barn, with one branch for a watering trough and another branch at a second barn for farm horses. The 3-inch pipe is then continued to the main stable and carriage house, where another fire hydrant is provided in addition to the supply for the coachman's rooms and the carriage wash. With a $2\frac{1}{2}$-inch fire hose attached to the fire hydrant, a fire stream could be thrown over the house under the available pressure, which did not exceed 32 pounds on the ground level.

The concluding section of this article, Part III., which will deal with reservoirs, tanks, standpipes, and the distribution system, will appear in the June number.

ELECTRIC TRACTION FOR MAIN LINES OF RAILWAY

By W. E. Langdon, Past President of the Inst. E. E., Late Supt. Engineer of the Electrical Department of the Midland Railway

THE step recently taken by the New York Central & Hudson River Railroad Company in determining to work the whole of the passenger traffic passing into and out of New York electrically for a distance of about 40 miles, and ordering for this about forty electric locomotives each capable of hauling a train of 450 tons at a speed of 60 to 65 miles an hour, is by far the most important step yet taken in the direction of the conversion of steam to electric traction on railways generally, for it means that that section of the New York Central road will, ere long, be operated entirely by electricity.

It is of interest to note that in adopting this course, although none other was feasible, the New York Central has followed the lines laid down by the City & South London Railway, in England—the pioneer line—but apart from the principle, the analogy ceases, for the reason that there can be no comparison between the locomotives to be used on the New York Central and those in use on the City & South London; the one is as a pigmy to the other.

It may be argued that the principle adopted by the City & South London Railway has been departed from by all those lines which have been electrified, or built purely as electric lines, in favor of the multiple-unit system. This is so, but in recognising the fact we must not forget the character of the railway and the nature of the traffic it has to provide for, together with many other conditions by which it may be attended. There can be little doubt that when we come to consider the electrical operation of main lines we shall come to the conclusion that the conversion can be effected only by the aid of the electric locomotive,—by following, in fact, the action of the New York Central and the City & South London systems.

It may be interesting here to recall the observations of the writer of this article in the concluding portion of a paper on "The Supersession of the Steam by the Electric Locomotive," read before the members of the Institution of Electrical Engineers several years ago.

"The life of a steam locomotive," it was there stated, "is not an indefinite quantity. Its replacement by one of more modern construction or of greater power, quite apart from its ultimate destruction by wear and tear, is an appreciable fact. As traffic increases, so additions have to be made. We see so many new engines ordered year by year. What is to prevent a railway company, instead of thus perpetuating its annual costs, setting apart portion by portion of their system for operation by electrical energy, and instead of ordering steam for, say, that portion of their system, to order electric locomotives, and thus to bring, piece by piece, their entire system under electrical operation?"

And in the final portion of his remarks in the discussion the writer emphasised this in the following words:—

"The electric locomotive to compete with the steam locomotive must be able to couple on to a train and haul

it away precisely as is now done by the steam locomotive. Section by section of a railway system might then become converted to the application of electrical agency without undue sacrifice of material, and with absolutely no inconvenience to the traffic."

In the equipment of those railways on which steam has been supplemented, or replaced, or is about to be replaced by an electrical service, the conditions would appear to have necessitated the provision of new stock throughout,—coaches as well as locomotives. The provision of electrically worked stock and plant must become, practically, an additional cost. Presumably, the chief object to be gained is to determine the trustworthiness and efficiency of the new agent, and to enable the railway companies to compete with their tramway rivals.

It is said that the economical results attending the electrification of the North Eastern Company's Tyne lines are satisfactory. On the other hand, however, there appear to be doubts of a similar result with regard to the experiment on the Lancashire & Yorkshire Company's Southport branch. The former claims a large increase in passengers over that portion of their system which has not been electrified. There is this to be observed with respect to the two cases. The Lancashire & Yorkshire line is to a large extent a residential line; its pressure arises morning and evening, whereas the Tyne branches experience a fair demand throughout the day. Again, no doubt, the latter derives some advantage from the fact that they do not generate the energy they make use of, and consequently pay only for what they require. This was not possible with the Lancashire & Yorkshire branch; that company had no alternative but to create its own power. Thus, when it is stated that the one is economical and the other is not so, it is well to bear their relative conditions in mind. Although the outlay for new coaches in either case could not have been very large, it is clear the cost of each installation would have been less if the provision had enabled the existing stock to be used.

It is in the conversion of main lines that the great advantages attending the use of electrical power will be found; but it would be fruitless to believe that railway companies will countenance the introduction of any system which would entail their throwing away the mass of rolling stock they now possess. Moreover, other questions arise which render such a course absolutely impossible. For instance, goods and mineral trains must be provided for, and if for this class of traffic locomotives have to be provided, there can be no reason why they should not be adapted to the traffic generally.

Whenever the conversion of main lines takes place it must be by sections, one section at a time, and this in itself entails the adoption of that course which is about to be inaugurated by the New York Central & Hudson River Railroad Company for the already mentioned 40-mile zone of the most important and crowded portion of its system.

The Great Western, the London & South Western and the Brighton lines in England are each seeking to meet the tramway competition on certain sections of their metropolitan system by supplementing the existing service by electric traction. Inasmuch as the greater portion of the traffic over these lines is residential, it is doubtful if, especially where the company has to generate its own current, this will be marked by economy other than in the possible prevention of further loss of traffic. Railway companies may in consequence jump at the conclusion that the introduction of electricity means an increase in both capital and maintenance, but such a conclusion would be manifestly unfair. These several railway companies are making an exceptional effort to regain, or to avoid the loss of, certain traffic, and its cost should be applied to that and not regarded as a criterion of what may be expected when the en-

tire traffic of the section is operated electrically.

It is important that this should be, in every instance, made clear to the railway company involved and, in fact, by every possible publicity to the railway interests at large. To reap the full advantage of electric traction, it must deal with the whole of the traffic passing over the section of line upon which it is established, and the demand for it must be fairly continuous and evenly distributed. This will be attained easily on main routes, and the main routes will be able, as a rule, to provide the energy required for the branch lines.

That great advantages and economics attend the introduction of electric traction on steam railways may well be anticipated, but it now remains to determine the details of the distribution of the current and the position and protection of the conductor.

NIAGARA FALLS POWER

DIFFERENT TYPES OF DEVELOPMENT

By George L. Clark

NEARLY every type of water power development known to the art may be seen about Niagara Falls. There we find a deep, vertical shaft or pit near the intake, with water wheels at the bottom, and a long horizontal tunnel for carrying off the tail water to a point in the river gorge below the falls. There, too, is the open surface canal that leads water from the intake to a forebay at the top of the cliff at one side of the cañon, and delivers it to vertical steel penstocks that drop to a power house at the edge of the river below.

In a third case a long steel pipe line takes the place of a canal for leading the water from an intake above the falls to a point at the top of the cliff, whence it drops through steel penstocks to a generating station in the gorge. Still another plan is that by which a power canal, several miles long, draws water from the Welland Ship Canal, expands at several points into large storage reservoirs, and finally terminates at the top of the Niagara escarpment, whence steel penstocks run to a power station near the Lake Ontario level below.

Besides these existing plants, there is the proposal to dig a long open canal from the upper Niagara River, and conduct the water to a point in the gorge below the whirlpool. There is also the plan to excavate a tunnel with its head below the water level in the gorge above the Whirlpool Rapids, and its mouth below the whirlpool, about one and one-half miles down stream, where the power house will be located.

Even the underground type of electric water-power station is to have an example at Niagara Falls, if the proposal of one engineer should materialise. This is to sink a vertical shaft near the upper river to a depth approximately equal to the height of the falls, and at the lower end to excavate a room in the shale and limestone large enough for the generating machinery. From this underground power station, a nearby horizontal tunnel would carry the tail water from the wheels to some point near the foot of the falls.

Perhaps the most interesting suggestion in the way of new power developments at Niagara, is that to sink a vertical shaft at the upper end of Goat Island, and then to excavate a nearly horizontal tunnel from the foot

of this shaft to the lower end of the island, near the water level in the gorge. The power plant in this plan may be located either at the upper end of the island and have an equipment of vertical shafts, wheels and generators, or at the lower end of the island and near the tail water level.

Among the types of power development now represented at the falls, that with the vertical shaft or pit near an intake, the wheels at the bottom of this pit, and the generators at the tops of vertical shafts in a power house above, is the most common. This plan, first executed by the Niagara Power Company at their two generating stations on the American side of the great cataract, has since been followed by the Canadian Niagara Power Company and the Toronto & Niagara Power Company, whose plants are both located on the Canadian side of the falls.

Prior to the developments with deep wheel pits and long discharge tunnels, came that of the Niagara Falls Hydraulic Power & Manufacturing Company with its open surface canal extending from the intake above to the cliffs below the falls, and its power house at the foot of the cliff. This type of plant has its latest development in the works of the Ontario Power Company, whose generating station is being built in the gorge near the foot of Horse Shoe Falls; in this case, however, a long line of steel pipe, instead of a canal, brings water from the upper river.

Another plant of substantially the same type, though differently located as to Niagara Falls, is that which draws water from the Welland Canal through a power canal several miles long; this latter canal is enlarged at several points into storage reservoirs, and delivers water to steel pipes that run down the face of the Niagara escarpment not far from De Cew Falls. The energy generated in this plant is transmitted to Hamilton and other places.

In each of these types of development, whether it be the pit and tunnel with power house at the level of the upper river, or the canal or pipe line with a power house in the Niagara Gorge at the foot of the long line of escarpment that faces Lake Ontario, the general problem is the same. Namely, to utilise more or less of the total fall of about 327 feet made by the discharge of Lake Erie before it reaches the Lake Ontario level.

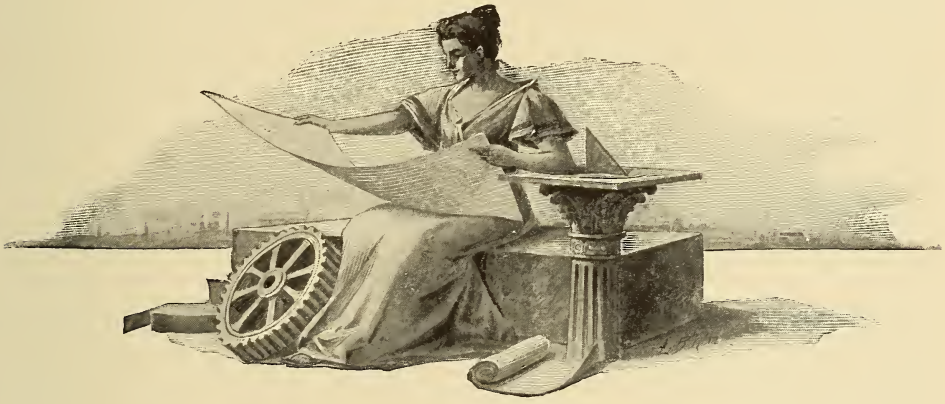
In order to render any great part of this fall effective at water wheels, they must be located near the lower level. This being so, a main distinction between the two general types of development is that in one the hole or pit in which the wheels are located must be excavated in existing rock, while in the other type the work of excavation has been done by nature, either in the Niagara Gorge or at the foot of the escarpment.

Where the level at which the wheels are placed is a natural one, the tailrace requires little or no excavation; this is the case in the Niagara Gorge, or at the foot of the escarpment. If the wheel pit is excavated to a great depth, then the tailrace takes the form of a long tunnel through the limestone or shale that underlies the Niagara region. When the power house is located in a natural depression like the gorge, or on the plain at the foot of the escarpment, a channel must be excavated on a pipe line laid near the natural ground level to bring water from the upper river.

Other things being equal, the location of the water wheels and power house at some natural level, instead of in and partly above an excavated pit, saves at the start most of the cost of such a pit. In a given case the length of the water conduit, whether canal, pipe line or tunnel, must be substantially the same, but a canal or pipe line is quite sure to have a materially lower cost than that for a tunnel of equal capacity. With a given head of water on the wheels, the length of steel penstocks must be about the same whether these wheels are in an excavated pit, in the gorge, or at the foot of the escarpment. The pit with wheels at the

bottom and a power house at the top has the further disadvantage that the length of shaft connecting each generator with its wheel must be about equal to the head of water, and that the weight and cost of the shaft and of its supports must be correspondingly great.

For these reasons, the plants now under construction about Niagara Falls have either their generators and wheels in pits as close as possible to the falls, so as to reduce the amount of excavation in both pits and tunnels, or else have them located in the gorge or at the foot of the escarpment and supplied with water through a canal or pipe line. For future plants designed to develop power with water from the upper river, canals or pipe lines are quite certain to have the preference.



Current Topics

It is safe to say that the incandescent lamp is the most familiar piece of electrical apparatus in existence and, from the operating standpoint, the simplest contrivance known to the art. Its reliability is now so well assured, through improved processes of manufacture, that it may fairly be considered as standardised. The absence of papers and discussions upon the subject at gatherings of electric light engineers, and in the technical press, bears witness to this. At the same time, the incandescent lamp is often abused in practice, and charged with faults which it has never committed. There is the question of life, for instance. Central station managers generally appreciate the need of knowing what the lamps on their circuits will produce in candle power and what they will stand in voltage variations. Consequently, many an electric lighting company maintains a testing laboratory at considerable expense in order that its equipment may be scientifically studied at regular intervals. The isolated plant, however, seldom tests its lamps. If it were necessary for each isolated plant in a city to fit up and operate its own testing laboratory there would be better reason for failing to study equipment. An organisation of isolated plants for the common good in a given city would be a step in the right direction. What is wanted is a certain community of interest. There are a good many engineering schools whose laboratories might just as well be testing commer-

cial lamps as the time-honoured samples which have done duty in the educational institutions themselves for several successive classes. The advantages of testing remain to be appreciated in many quarters. Even in installations buying current from central stations, it is a good thing to put a voltmeter plug into a lamp socket now and then. Presumably everyone realises the fact that a slight increase in voltage above normal tremendously shortens the life of the incandescent lamp, and yet plant after plant goes on, year in and year out, without making the simple periodic measurements which will show how matters stand. It is safe to say that a consumer located two or three miles from the central station who puts a voltmeter across his meter circuit, supposedly 500 volts constant potential, and obtains readings varying from 570 to 260 volts, does not regret having made the test.

A GREAT deal remains to be done in the proper use of incandescent lamps, however, besides keeping an eye upon their life. The illumination of rooms under different conditions is a subject little understood by the general run of isolated plant owners and operators. It is unfair to the incandescent lamp to charge it with injuring the eyesight if the lamp is so installed that its direct rays enter the eyes without the intervention of a shade. There would be no need of calling attention to such a simple matter as this, were it not for the constantly recurring examples of bad practice. It is strange that in so many plants there should be so much complaint about the dimness of incandescent lamps which have been in use for some time, when the simple process of wiping the bulbs with a damp cloth would increase the illuminating efficiency wonderfully. There is little use in discussing the expediency of raising the voltage, rewiring the leads, or worse yet, cutting out the installation in favour of gas, as long as the incandescent bulbs are allowed to accumulate weeks' deposits of dust and grime. Perhaps this form of neglect is the greatest abuse which the incandescent lamp is obliged to suffer. It is a rare sight to find anyone dusting lamp bulbs in factory or office or even dwelling.

THE recent successful achievement of the piercing of the Simplon has recalled a parallel feat of engineering skill, although on a comparatively very insignificant scale, yet carried out more than twenty-five centuries ago. According to the London "Engineer," Dr. Bertholet, of Basle University, has drawn attention to this remarkable work, which seems to be the first recorded instance of tunnelling in the rock. Of King Hezekiah, who is supposed to have reigned in Jerusalem from 727 to 699 before the Christian era, we are told—II. Kings xx. 20—that he "made a pool, and a conduit, and brought water into the city," a statement confirmed by Jesus Sirach —xlviii. 17—who wrote:—"Hezekiah fortified his city by leading water into it, and he bored through the rocks with bronze and dammed the water into a pool." This boring through the rocks with bronze, in the opinion of modern scholars, refers to the Shiloah Tunnel through which the water of Mary's Spring, lying to the east of Jerusalem, was brought to the city into the pool of Siloam, mentioned in the fourth Gospel. Hezekiah's purpose seems to have been twofold—to supply Jerusalem with good water in case of a siege, and, at the same time, to cut off the water supply of the enemy. The latter reason is clear from a passage in Chronicles—xxxii. 4—where it is related how the people gathered together and "stopped all the fountains and the brook that ran through the midst of the land," to forestall the Kings of Assyria, should they come to beleaguer the city. In the same chapter—xxxii. 30—it is said more explicitly that Hezekiah

"stopped the watercourse of Gihon, and brought it straight down to the west side of the city of David." The surface canal, rediscovered in 1890, was constructed in the reign of Hezekiah's predecessor, and is probably referred to by Isaiah as the "waters of Shiloah that go softly." It was thus replaced by a much more efficient device, namely, an underground conduit.

So far, then, the at present existing Shiloah Tunnel had been identified with the work of the old Jewish king, but it was reserved for a mere chance to reveal the technical details of this ancient example of rock-piercing. In the year 1880 some boys, while bathing in the Shiloah Tunnel, noticed an inscription, which, on examination, proved to be in old Hebrew characters, only slightly less primitive in form than those of the Moabite stone, while further investigation showed that the writing must be regarded as contemporary with the construction of the tunnel itself. In spite of a few lacunæ, the inscription has been read, and runs to the following effect:— "(Completed is) the piercing. And this was the manner of the piercing. When yet the pick of the one . . . against the other, and when there were still three ells (to pierce), then (one could hear) the voice of the one, who called to the other; for there was (a cleft) in the rock on the south side . . . and on the day of the final piercing the rock hewers struck against each other, pick against pick. Then flowed the waters from the outlet into the pool 1200 ells distant. And 100 ells was the height of the rock above the heads of the hewers." This description leaves no doubt as to the boring of the tunnel having been commenced from both ends simultaneously. A curious confirmation of the fact is, however, afforded by the circumstance that the marks of the tools run in opposite directions in the northern and southern halves.

The work was not carried out without hitches. It has been discovered that the direction had several times to be corrected, galleries already begun having been again abandoned. It would almost seem from the expression in the inscription that the successful meeting of the working parties was due to their hearing each other's voices. The compass, although said to have been known at a very early date in the Far East, could hardly have been at the disposal of Hezekiah's engineers. The result was that the channel was a long way out of the straight line. The present length of the tunnel is 580 yards, the equivalent to which is, in round numbers, the 1200 ells of the inscription, while the geometrical distance between the point of departure and the point of completion of the tunnel is only 363 yards. The meeting point of the tunnel borers is not far from the middle. The breadth of the tunnel varies from 3 feet to 2 feet; the height falls from nearly 10 feet at the southern opening, where presumably the constructors availed themselves of the natural fault in the rock, to a foot and a half, rising again to 6 feet at the northern outlet. In strong contrast with the failure of the constructors to keep in a straight line is the accuracy observed by them in maintaining the same horizontal plane throughout the work. The whole difference in level amounts to no more than a foot. This circumstance has even led to the surmise that the old Israelites must have possessed a primitive instrument analogous to the modern spirit level for determining the horizontal direction.

According to the Hon. Charles A. Parsons' prediction, made in his recent presidential address before the Institute of Marine Engineers, the steam turbine will soon supersede the reciprocating engine in vessels of 16 knots sea speed and upward and of over 5000 indicated horse-power. It will also probably be used for vessels

of speeds down to 13 knots and of 2000 tons and upward, and possibly also in even slower vessels, in course of time. At present it might, he thought, be said that the most suitable field comprises about one-fifth of the total steam tonnage of the world. It must be remembered, however, that the speed of ships tends to increase, and the turbine to improve; thus the class of vessels for which the turbine is suitable will increase. It seems probable also that a combination of the reciprocating engine and the turbine will be found the best machinery for vessels of the tramp class in the immediate future. That field is a very large and important one and deserves more attention than it has yet received. The main feature of this combination of machinery is, he said, that the full measure of expansion essential to economy can be obtained. Attention was drawn to the fact that if the indicator cards of a tramp steamer were examined, it would be found that the steam is usually expanded down to about 7 pounds pressure absolute, and that it is then released into the condenser, and that the remaining energy—between 7 pounds down to, say, 1½ pounds, or 27-inch vacuum—was almost entirely lost. The turbine is able to save 70 per cent. of that wasted power and apply it to help in driving the vessel. The additional power gained by use of a low-pressure turbine has been calculated at between 15 and 20 per cent. of the whole now realised—a gain of the same order as was obtained in the advance from the compound to the triple engine.

In September, 1900, we published an exhaustive article by Benjamin Taylor, F.R.G.S., on the subject of "The World's Coal." In the course of that article the necessity of a fresh enquiry into the coal resources of Great Britain was urged. It was pointed out that the Royal Commission appointed in 1871 to enquire into the whole question of the coal supply had been wrong in their expectations. That commission estimated that the population of the United Kingdom in 1901 would be only 35,000,000, and they estimated that in 1901 the consumption and exports of British coal would require an output of 174,000,000 tons. The output even in 1899 was 220,000,000 tons. It was estimated by Mr. Taylor that the output in 1901 would be 225,000,000 tons, or over 50,000,000 tons more than the estimate of the Royal Commission. It was actually 225,000,000 tons in 1900, and reached 227,000,000 tons in 1902. The estimates put forward by the Royal Commission of 1871 were mainly those of Prof. Stanley Jevons, who limited the duration of the British coal fields to 110 years. This commission assumed that the British exports would not exceed 12,000,000 tons, whereas in 1899 they were 43,000,000 tons. In 1904 they were 48,000,000 tons. Such enormous differences, it was contended, called for fresh enquiry. The plea was warmly supported and late in 1901 a Royal Commission, composed of colliery owners, coal exporters, miners' agents, mining engineers, and professors, was appointed "to enquire into the extent and available resources of the coal fields of the United Kingdom and the rate of exhaustion which may be anticipated." The report of this commission is full of valuable material, but at the moment we can deal only with some of the salient points.

The Royal Commission of 1901, after three years' investigation, shows that the quantity of available coal still in British earth is enormous. It condemns the export coal tax and pronounces against those theorists who advocate restriction of the export of coal from a mistaken view of the economics of industry. The conclusion of the commission as to the coal in the United Kingdom which has yet to be worked is that the available quantity of coal in the proved coal fields is over

a hundred thousand million tons. The coal output of the last 34 years has been 5,694,928,507 tons, and the total coal still available is 100,914,-668,167 tons. Therefore, there remains to be worked eighteen times as much coal as was actually worked from 1870 to 1903. This total, however, does not really represent the full resources. It includes only the mineral available in the "proved" coal fields, less than 4000 feet deep, and in seams over 1 foot thick. The geological committee of the commission estimate that there will be found in the concealed and unproved fields at depths less than 4000 feet, 39,483,-000,000 tons. Adding the unproved to the proved coal in sight, makes a total of 140,397,000,000 tons still to be worked, or about twenty-five times as much as the total output of the last 34 years. But this is not all. In the proved coal fields it is estimated that there are 5239 million tons at a lower depth than 4000 feet, and in addition to the unproved coal fields as above there are 854,000,000 tons under the sea on the Cumberland Coast and 283,000,000 tons under the sea on the Carmarthen Coast. The mining engineer of the future has to solve the problem of mining coal at a lower depth than 4000 feet and from seams at all depths of less than 1 foot in thickness; and no doubt engineering will rise to the occasion in due time and add incalculably to the available coal of Great Britain.

As to the coal export tax, the final conclusion of the commission, after full value has been given to the counter-influence of falling freights, is that an export duty must restrict the tonnage exported, and that the burden of the tax presses more heavily on coal which in value is slightly over the margin of price at which coal is exported free of duty. In the matter of exports, which was dwelt on in Mr. Taylor's article in 1900, the Commissioners are of the opinion that "in view of the estimated coal resources of the country, and if our anticipation is correct, namely, that the present rate of increase in the output will soon be checked by natural causes, there seems no present necessity to restrict artificially the export of coal in order to conserve it for our home supply." The Commissioners embody in the report evidence that the maintenance of a large coal export trade is of supreme importance to Britain and essential to the prosperity of the coal producing districts. The large production of the last 34 years has been made up twice over by the discovery of 10,707,382,-769 tons of available coal more than the estimate of the Royal Commission of 1871. The latest Commissioners are convinced that the rate of increase of output will in time slow down, then become stationary, and then decline. They look both to greater economy in working and to the application of improved methods and appliances for getting a greater percentage of coal than is estimated as available. The Commissioners are earnest against waste, both in getting and in using coal. The report goes deeply into this subject, describing the superior methods of Continental producers in preparing coal for market, advocating briquette-making, transmission of power instead of coal, etc., etc. The Commissioners' conclusion, arrived at after a review of all suggested substitutes, like oil shales, alcohol, the tides, and so forth, is that coal is Britain's only reliable source of power, and that there is no real substitute.

An interesting reason why ships' bottoms painted with ordinary oil paint show considerably more rust than those painted with special compositions was given some time ago by A. C. A. Holzapfel, in a paper before the Institution of Naval Architects. The rust is almost invariably due to the presence of moisture on the surface of the ship plates before the paint or composition is applied. The paint-

ing of ships, as Mr. Holzapfel pointed out, is generally done in the daytime, when the temperature surrounding the vessel is about 10 to 20 degrees higher than the body of the ship. As a consequence, moisture is generally present on a ship's plates while she is being coated; the quick-drying varnish paints which are used as a priming in connection with the anti-fouling are, however, particularly well adapted to prevent damage from the presence of this moisture, for during application the moisture becomes mixed with the paint and evaporates with the several light hydro-carbons which are generally contained in the paint.

This is a similar process to the familiar one used by chemists to remove the moisture out of glass tubes. These are rinsed out with alcohol, and with the alcohol any moisture which may be present will evaporate.

THE first paint applied to new vessels, says Mr. Holzapfel in the same paper, is mostly the so-called builder's paint. This has no capacity for firmly adhering to the close grain of a new steel plate. The usual priming of anti-fouling composition has also often been tried and found little better. These unsatisfactory results are also largely due to the bloom and mill-scale present on new plates, and to moisture frequently present between the metal and the paint. The navies of most countries, therefore, specify that the plates of their vessels, before being riveted into position, are to be pickled; by this process the millscale and bloom are removed, and the surface of the metal is sufficiently broken to give the paint proper adhesion. Shipowners, however, find the pickling process too expensive, and several of them specify that their vessels are to be launched without any paint on their bottoms. A few weeks or months later, after their outfit is completed, these vessels are docked and coated with three coats of composition, which then adheres much better. The first of such coats should be a specially prepared, slow-drying composition, sufficiently liquid to mix with any rust still present on the surface of the plate. How far this launching without paint may be adopted where the water contains many impurities is to be questioned; but, generally, this process is as effective as the pickling, and considerably cheaper, and recommends its general adoption by shipowners. The two or three coats of builders' paint usually applied he considers to be labour and material wasted, as most or all of it falls off during the first year or two of the vessel's existence, taking off the composition with it, and necessitating frequent docking and repainting.

THE annoyance sometimes resulting from the selling of machine tools at long range is exemplified in a recent article in "The Iron Age" dealing with the trials of machine tool sellers. A New England manufacturer of pipe-cutting machines, it is told, sold such a machine to an Australian customer to go back into the interior, which was an expensive matter of freight alone. Soon after its delivery a letter was received stating that the machine would not work. The reply was that it must work, for it had been carefully tried out in the shop before shipment. Correspondence continued, each interchange of letters consuming several months, the customer all the while insisting that the machine would not work because the centreing vise would not correctly align the work. Finally, in desperation the manufacturer wrote offering to take back the machine if the freight charges would be paid by the customer, providing the machine proved to be all right when it arrived at the shop. It cost $350 for the freight on a $250 machine, which made a complete circuit of the globe, and it was found that an Australian workman

had removed the vise jaws and in returning them had reversed their positions, throwing the vise more than half an inch out of line with the dies, and yet no one had awakened to the idea that such a discrepancy must have a quick and easy solution. This same manufacturer sent a machine to a coal mining company and soon afterward received a letter that it "wouldn't work." Letters failed to get a more detailed account of the trouble, and a representative was sent to the seat of the trouble to see for himself what the matter was. Arriving on the scene he was told that the workmen were "afraid they would break the machine." He told them to go ahead and he would risk it, and they did, and the work went along just as the machine was designed to do it. The manufacturer sent the bill to the coal company for his representative's expenses, but it was not paid. The cost of the episode was thus another charge added to the long list of entries under the head of "experience."

J. IRVIN CHAFFEE

A BIOGRAPHICAL SKETCH

By William Ledyard Cathcart

THE school of naval architecture and marine engineering, established by the late William H. Webb at Fordham Heights, New York City, has had, during its relatively brief existence, its full share of the work of American institutions in training students in the science of marine construction and has won such success as to prove fully the wisdom of the gift, in buildings and endowment, which crowned fitly its founder's long career.

Mr. Webb was one of the foremost American shipbuilders at a time when the United States led the world in that art. His skill was shown not only by a great fleet of merchant vessels of every class, but also in warship construction for the United States and other governments. Two of his ironclads will always be noteworthy in naval history—the "Re d'Italia," sunk in Tegetthoff's famous charge at Lissa, and the "Dunderberg," built in 1864 for the United States, a vessel of 7000 tons and 15.3 knots' sea-speed, whose design embodied many features then novel, but now regarded as essential.

Always a man of much public spirit, Mr. Webb was especially interested in educational matters. The difficulties which, in his youth, he had met in acquiring a knowledge of the science of his profession, together with his desire to found an institution which would be a public benefaction in its service to able and deserving young men, led to the establishment of Webb's Academy, for which he provided a liberal endowment that courses in naval architecture and marine engineering might be maintained without cost to the students admitted under the academic regulations.

The institution, thus created, was incorporated in 1889, dedicated in 1894, and, three years later, sent forth its first graduates. The latter now number about 70, all being at present employed at the Navy Department, Washington, at government inspection offices, or at private shipyards on the coasts and lakes. The growing value of the service rendered by the academy to naval and marine interests is shown by the fact that, in recent years, all students are, as a rule, provided with positions before graduation.

In the professional success of this institution, Prof. J. Irvin Chaffee, the present head of its faculty, has been, practically from the beginning, a leading factor, since he has combined with his ability as an educator unwearying labours for, and fidelity to, the interests of the institution and its students. As a former colleague of Professor Chaffee during the formative stages of the academy's growth and with full knowledge of the difficulties then met and overcome, the writer may say, without hesitation, that to Professor Chaffee, more than to any other, is due the organisation, discipline, and steadfast adherence to high ideals which have made the graduates of Webb trustworthy and able professional men.

Professor Chaffee is remotely of English descent, his family having been long settled in New England. The first of the name in America was Thomas Chaffee, who reached Hingham, Mass., in 1634. From him and, in the maternal line, from Capt. Benjamin Church, the hero of King Philip's war, Professor Chaffee is descended. It is interesting to note that, to the American branch of this family there also belong General Chaffee, Chief of Staff, U. S. Army, ex-Senator Chaffee, of Colorado, and a number of clergymen and physicians of more or less prominence.

Professor Chaffee received his early education in the public and private schools of East Providence, R. I., and entered Brown University in the class of 1883. In 1882, while still in his senior year at college, he was appointed principal of one of the grammar schools of East Providence and established the first high school course instituted there, maintaining meanwhile, by hard labour, his standing at the university and receiving his degrees in due course. Later, he followed, for a time, advanced work in mathematics and physics at the University of Berlin, Germany, and at Johns Hopkins University. His subsequent service as an educator was varied and responsible, he having been principal of high schools or superintendent of schools at several locations in New England, including Providence, R. I., and Stratford, Conn. In 1895 he was appointed professor of mathematics at Webb's Academy, which chair he still holds.

His marked executive ability—a quality which, as a rule, is not strongly developed in the educator—led, in 1901, to the appointment of Professor Chaffee, in addition to his professional duties, to the post of resident manager of the entire institution founded by Mr. Webb. The considerable responsibility involved in this position is shown by the fact that Mr. Webb's benefaction was dual in its purpose. His institution is known officially as Webb's Academy and Home for Shipbuilders, and its functions are not only to train students as naval architects and marine engineers, but also to provide a home for veteran shipbuilders who, from business misfortune, may care to find safe harbour there. It will be seen that Professor Chaffee's duties, as head of the academy faculty and as resident manager, make him, under the board of trustees, the executive officer in the detailed administration of the Webb institution and endowment.

For such a post, it is apparent that qualifications of a high order are essential, and these it is safe to say Professor Chaffee possesses in adequate measure, judging from the steady support which he receives from the trustees, the success of Webb students in professional fields, and the regard in which he is held by the alumni of the academy. With a rigid sense of duty and an inherited love of learning, he is gifted as well with broad sympathies, a keen and kindly personal interest in those under his care, and an unfailing loyalty to his ideals and his friendships. These traits of character indicate the causes of Professor Chaffee's success and his fitness for the work he has chosen, that of shaping for good ends the lives of young men.

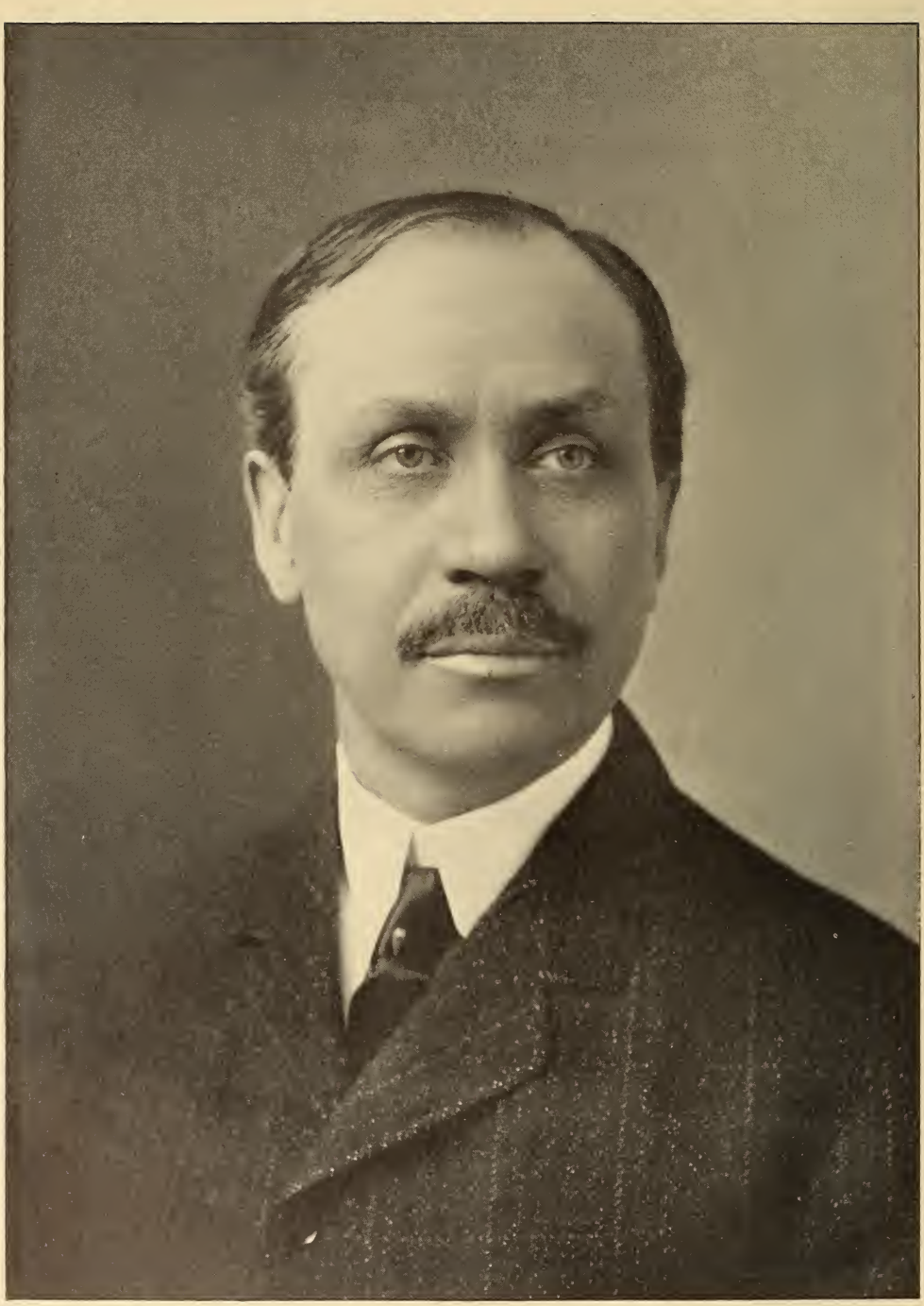


PHOTO BY E. CHICKERING & CO., BOSTON

GEORGE HALE BARRUS

SEE PAGE 163

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CASSIER'S MAGAZINE

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SELF-PROPELLING ELECTRIC FIRE-ENGINE, LADDER WAGGON, AND FIRE ESCAPE USED BY THE PARIS FIRE BRIGADE

AUTOMOBILE FIRE ENGINES

By George Glendon

IT has long been obvious that the application of the automobile to fire-engine work is highly desirable, owing to the various important advantages which could be derived from it. But when the problem came to be tackled there were so many difficulties encountered that success has been slow in coming. Indeed, as yet the motor fire-engine is found in comparatively few brigades, and London city still presents the extraordinary spectacle of all its fire-fighting appliances being transported by horse power, though one of its suburbs has just set it a good example.

Paris, New York, Boston and Liverpool are amongst the big centres which have introduced motor fire-engines into their services, and the results are so satisfactory that in the next few years their example may be generally followed. Considerable skepticism yet prevails, however, amongst the more conservative bodies, and it is difficult to make them realise that modern conditions call for something better than horse traction.

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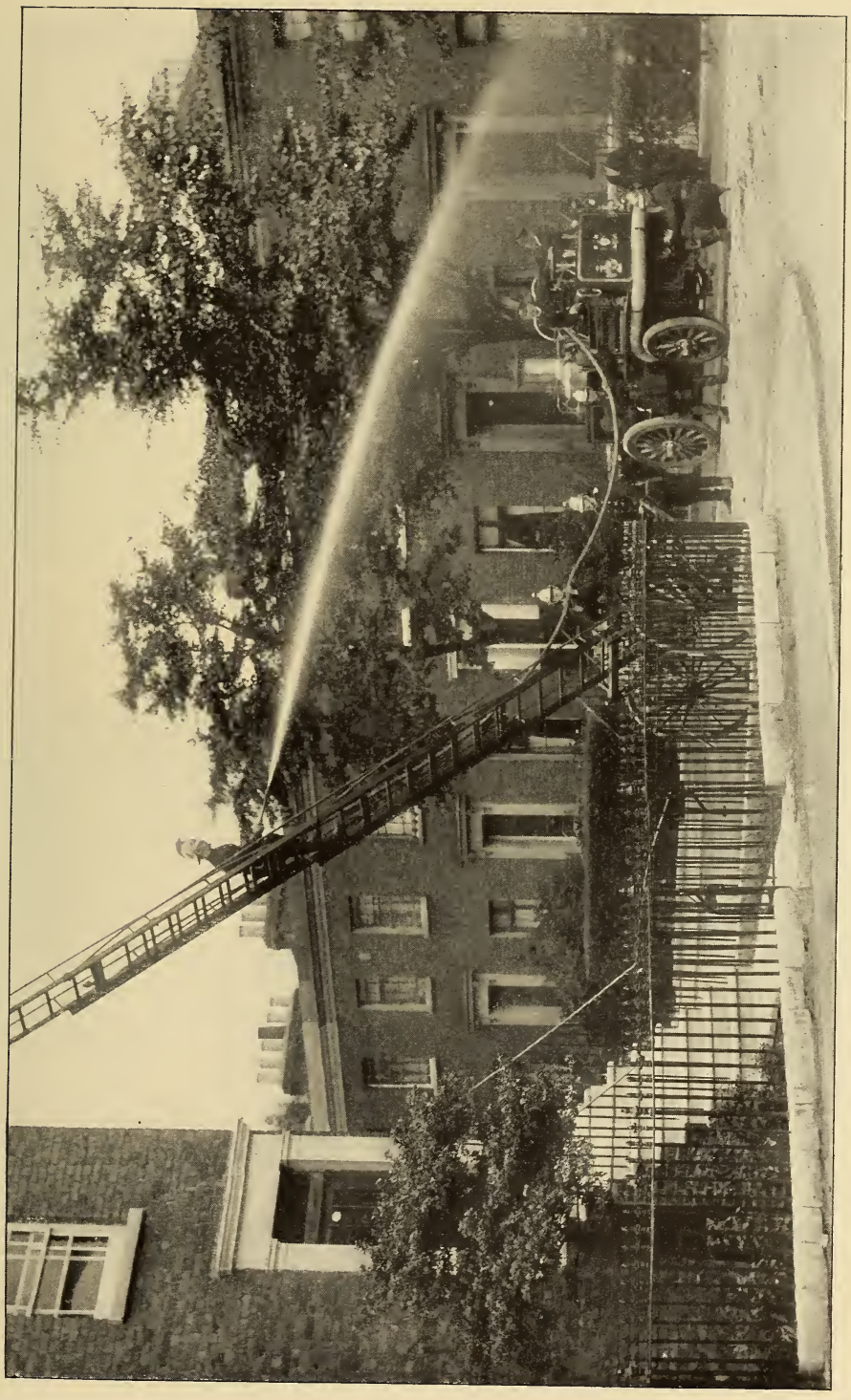
TRIALS WITH A STEAM MOTOR FIRE-ENGINE, MADE BY MESSRS. MERRYWEATHER & SONS, LTD., LONDON. THREE JETS BEING THROWN SIMULTANEOUSLY FROM THE ONE ENGINE



DISPLAY WITH A MERRYWEATHER CHEMICAL STEAM MOTOR ENGINE

A PETROL MOTOR FIRE-ENGINE AND FIRE ESCAPE MADE FOR THE FINCHLEY (NORTH LONDON) FIRE BRIGADE BY MESSRS. MERRYWEATHER & SONS, LTD., LONDON. THIS OUTFIT COMPRISES A CHEMICAL CYLINDER FOR FIRST AID, A HIGH-PRESSURE FIRE PUMP, AND A 50-FOOT FIRE ESCAPE

FIRST AID PETROL MOTOR FIRE-ENGINE SUPPLIED TO THE LEICESTER, ENGLAND, CORPORATION. CAPABLE OF RUNNING 35 MILES AN HOUR. BUILT BY THE WOLSELEY TOOL & MOTOR CAR CO., LTD., ADDERLEY PARK, BIRMINGHAM

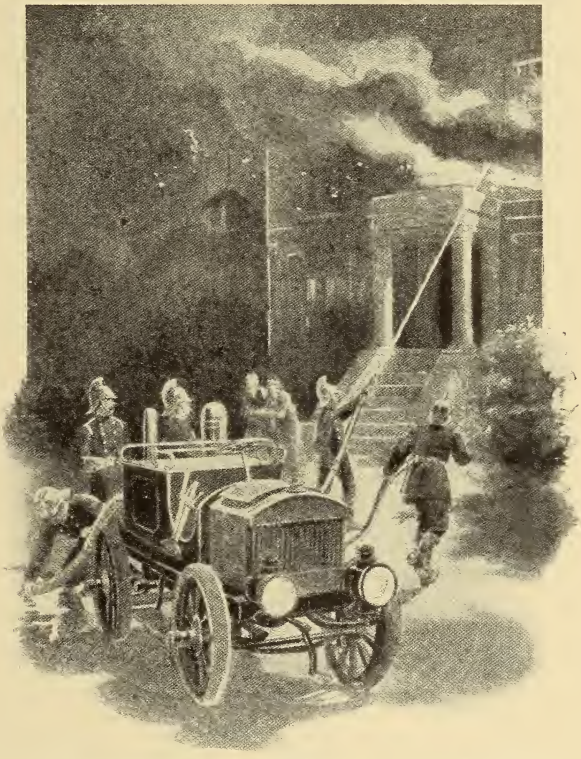
Time is the first great element of success in fire-engine work, and there is clearly an advantage in using a motor fire-engine which can travel at over twenty-five miles an hour, as compared with a horse team which could not exceed, say, fifteen miles an hour, and probably could not maintain that speed for any length of time.

Of course, it will be pointed out that in the tortuous streets of some cities high speed is not possible; but the fact remains that an ordinary motor car can travel through any part of a city at a much better average speed than the fastest horse-drawn fire-engine with a way specially cleared for it. There is something almost childish in the spectacle of a big city fire brigade going to work with its horse teams, as, with all the traffic huddled out of the way, the horses dash along at a speed which would be thought very moderate by any motorist, and with which the ordinary cyclist would have very little difficulty in keeping pace.

The childishness of the display is all the more marked when the speed is compared with that of the electric motors in Paris, the thirty-mile-an-hour Merryweather motor engines now used in Liverpool, or the thirty-five-mile-an-hour first-aid engine which the Leicester corporation has just acquired; or, lastly, with the combined fire-engine and escape which has lately been adopted in North Finchley, one of the most enterprising suburbs of London.

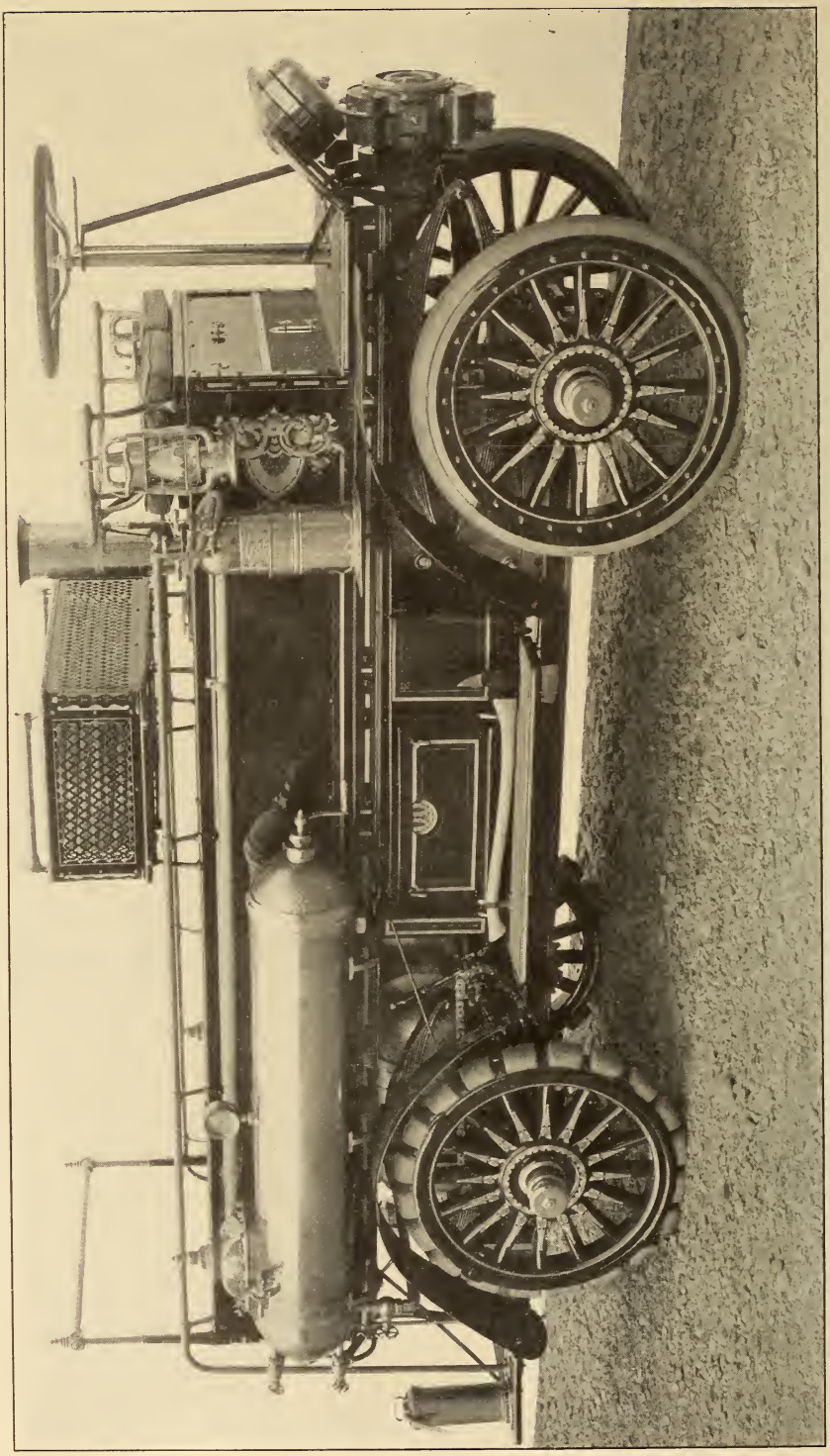
The manner in which a modern fire brigade gets under way is excellent generally in all respects; but the horses, by reason of their limited speed, cause much waste of time in getting to and from a fire. A motor vehicle with its great reserve power can spurt with marvellous rapidity, and then with its powerful brakes can reduce speed very quickly. It can therefore safely maintain a higher average speed than the horses, and may be steered to greater nicety in congested districts.

In some of the newer motor fire-engines a very effective chemical jet or spray is used to pump on the fire at first, and this can be started the instant the engine arrives at the scene of the fire. Reserve water tanks are carried on the Paris electric engines, and the motor that drives the car can instantly be switched on so as to work the pumps which draw their supplies from the reserve tanks. These provide sufficient water for about five minutes' work, and in this time the firemen will usually have succeeded in connecting with the local supply.



AN ELECTRICALLY PROPELLED AND MOTOR-DRIVEN FIRE-PUMP, ALSO OF MERRYWEATHER MAKE

Thus from the instant the car pulls



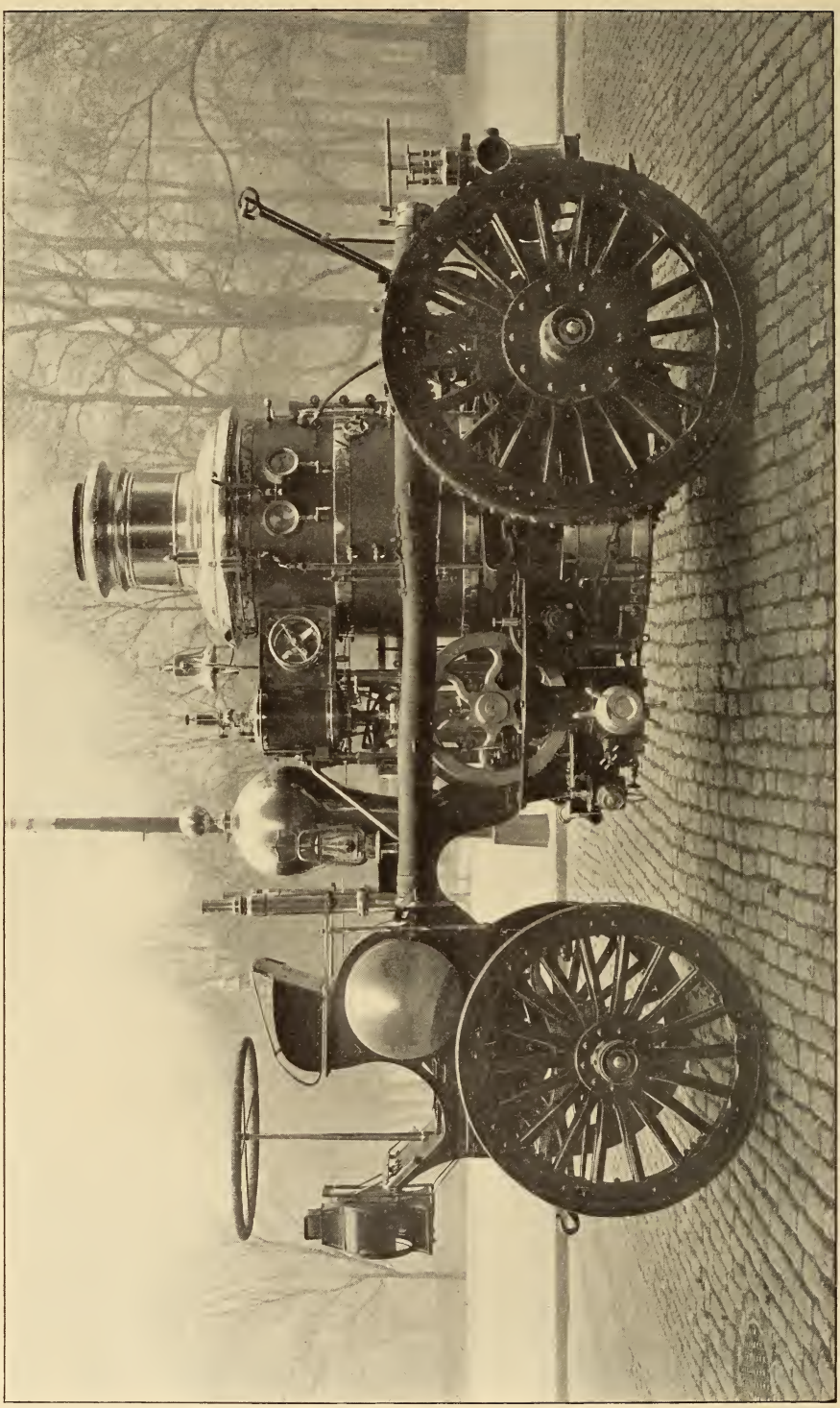
STEAM MOTOR CHEMICAL ENGINE MADE BY THE AMERICAN LA FRANCE FIRE ENGINE CO., ELMIRA, NEW YORK

STEAM MOTOR FIRE-ENGINE OF THE LIVERPOOL FIRE BRIGADE, BUILT BY MESSRS. MERRYWEATHER. & SONS, LTD. CAPABLE OF RUNNING AT 20 MILES PER HOUR

up at the fire the flames are being attacked, and a great deal of precious time is saved. In Paris, too, the fire escapes are of a novel type, and are carried on electric vehicles. In fact, the complete travelling equipment of one Paris station is provided with electric motors, and thus men and machines are conveyed to the scene of operations in remarkably quick time.

Electric motors have this advantage, that they are always ready, and start even more quickly than petrol motors, though the modern multi-cylinder petrol motor is now but a shade inferior to it in this important respect. The advantages of both these systems over the ordinary steam engine is that they can be got into running order "from the cold" in a few seconds. It is but a question of time, probably, before the pumps will also be driven by similar motors, for this will avoid the necessity of keeping up fires in the engines as at present; and as the heavy boiler and accessories will be dispensed with, there should be considerable saving in weight.

Steam generated in "flash" boilers is used on the Merryweather type of motor fire-engine, of which two are employed in the Liverpool brigade with great success. This boiler uses petroleum as fuel, and the outfit can be got going under its own steam within a minute of the alarm being given. A speed of twenty miles an hour is possible, and the engine has a chemical jet which can be brought into instant use. The new engine supplied to Leicester has a petrol motor, and this vehicle can attain a speed of thirty-five miles an hour, being thus perhaps the fastest fire-engine in the world. The combined motor fire-engine and fire-escape used in Finch-



AUTOMOBILE STEAM FIRE-ENGINE BUILT BY THE AMERICAN LA FRANCE FIRE-ENGINE COMPANY, ELMIRA, NEW YORK

ley, North London, is also a speedy vehicle.

By using the same motor to actuate the propelling mechanism and also to work the pumps, much economy in space and weight is effected; but in some systems it has been found advantageous to have a small auxiliary motor to work the pump connected with the reserve tanks. The great superiority of the motor engine as compared with horse traction is that a better average speed can be maintained, and the engines will be of use over a greater area. The system of these motors is such that they can be rapidly brought into action at any moment, and, except when in actual use, they entail practically no working cost.

There seems great scope for the light "first-aid" engine, and its adoption generally should add considerably to the efficiency of fire brigades in large centres. This vehicle would act as a kind of advance guard to the main force of the brigade, and, being of light weight and fitted with pneumatic tires, it can attain very high speeds in a short space of time. Its proportions are very handy, making it most suitable for getting quickly to a fire before the full strength of the brigade can turn out. It would be specially useful for outbreaks which from the first appeared not to be of a very dangerous character.

A really small fire-engine of this type takes up little more room than an ordinary motor car, and for its upkeep and working a few men would be sufficient. It could thus be garaged in small sub-stations, requiring no more extensive accommodation than is necessary for horse-drawn vehicles.

A number of sub-stations provided with speedy first-aid motor engines would usefully supplement the work of the central stations, and would allow them to reserve their energies for really serious work. The motor fire-engine, with its ever ready motor, could be stored in the simplest form of building; it would always be ready, and could be worked by a small staff of men. It should prove a boon both to the fire service and the public, for it would vastly simplify the work of the former, and add considerably to the security of the latter.

SOME PROBLEMS IN ELECTRIC MOTOR DRIVING

By H. S. Knowlton

THE variety of problems which arise in the application of motors to different kinds of machinery is scarcely appreciated outside the enginering circles directly concerned in such work. In view of the success which has been attained with motor drives throughout almost the entire range of industry, there is in some quarters an impression that it is a simple matter to pick out a standard motor for a particular service, or else design a special one better adapted to the conditions. As a matter of fact, motors can be easily chosen for work which simply repeats other experience, but in installations where the conditions of operation are not closely defined, the selection of electrical machinery is a problem demanding experienced judgment and great care, if economical results are to be secured.

It is somewhat remarkable that the feature of motor driving which primarily led to its adoption in the early days of electrically-operated machinery, does not to-day occupy as prominent a place among the reasons which decide for the use of motors in industrial establishments. That is, the saving in power effected by electric driving is but one of many inducements to change from obsolete to modern methods of machine propulsion.

In many industries the cost of power is less than 5 per cent. of the total cost of manufacture, while the labour cost frequently runs as high as 50 per cent. of the whole. Hence, a saving of even 40 per cent. in the cost of power may reduce the manufacturing cost but 1 or 2 per cent. In these days of close competition, even as small a percentage as this is generally worth saving, so that if no other reasons for the adoption of motor driving existed, it would in many cases be justified by the economy gained in power. A small percentage of a large sum is not to be despised in the annual balance sheet.

Probably the greatest advantage of the motor drive is the increased production which almost always results from its use. This point is of the utmost importance in the modern factory, and is profitably sought as long as the cost of manufacture per unit of output decreases or remains stationary. For this reason it would often pay to equip a plant electrically, even if the actual consumption of power increased through the use of motors. In the majority of cases, however, the power cost per unit of product falls, making a clear gain in the process of manufacture.

One cannot easily exaggerate the importance of working a modern industrial plant at full capacity. A load factor of from 75 to 100 per cent. is as much to be desired in a factory as in an electric power station, and the motor drive goes a long way toward establishing such figures. This is what we mean by the economy of electric driving; in its broadest sense, a very different matter from the efficiency of the motor itself, with its connecting belts, gears or direct coupling.

The economy of motor driving is composed of many factors. Some of these are: Greater efficiency in the

application of power; safety to employees; reduction of floor space in some cases; increased reliability and freedom from stoppage in case part of the power-supplying machinery fails; increased production, due to almost perfect maintenance and regulation of speed; elimination of dust and dirt; flexibility of machine location with regard to light and sequence of operation; facility with which the existing equipment may be added to or changed, and this without shutting down the entire department concerned; independent operation of each motor-driven group or machine without interference with other processes; ability to run any machine group overtime without waste of power in idle shafting, pulleys and belts; in new plants, lighter roof structures and decreased cost of building; ability of motors to carry severe overloads temporarily without injury or noteworthy slackening of speed; possibility of bringing tools to the work instead of the work to the tools where the job is a heavy one; elimination of wasteful transportation, and in many cases, decreased labour cost per unit of output.

The extent to which these various economies, and others, can be realised in a given installation varies widely, but without much question the two most essential are increased production and decreased cost of labour.

Perhaps the most difficult question to determine in selecting a motor outfit is whether to have individual or group driving. Of late there has been a marked tendency toward the equipment of every machine with its own motor, but in some quarters this subdivision is believed to have gone too far. Like the time-honored question of the debating society—"Resolved, that the pen is mightier than the sword"—the choice between group and individual driving cannot be decided off-hand. So much can be said on each side that perhaps the best plan is to point out the line of attack upon the problem suggested by recent observations in motor-driven shops.

In a machine shop the variety of tools is so great, and the range of speed so considerable, that the best practice seems to incline toward the individual driving of the equipment. On the other hand, a cotton mill containing thousands of spindles, and requiring little speed variation, seems best adapted to extensive group driving. As Dr. Louis Bell expresses it, "the weight of evidence as to proper subdivision of power is a separate motor, not for each machine, but for every operative unit, whether that unit be an individual drill-press or a dozen screw machines. Such a combination of group and individual driving greatly lowers the first cost of the installation, and gives, on the whole, better economy than the extreme plan of a motor for each machine."

The percentage of time that a machine is in operation is an important consideration in the choice between individual and group driving. It would seem that as this percentage increases, the more should the case be treated by grouping like machines together, provided that the speed variations desired are not excessive and sudden. Thus, a group of drill grinders constantly used, and with but few changes in speed, are preferably operated from a single motor through a short line shaft, but machines of the shaper and planer types, boring mills, and in some cases drill presses, may usually be profitably driven by individual motors. Much depends upon the character of work performed by the machinery.

The cotton mill spindles pass through the same cycle in groups; they are in continuous operation at the same time, and hence are particularly favorable subjects for group driving. But in extending the limits of the group drive, one must not go too far, else the increased losses in shafting and belts will cost more yearly than the fixed charges upon the excess cost of small motors over the grouped installation.

In many plants a combination of group and individual driving is the best solution of the problem, and

wherever the character of operations performed varies widely, it will usually be found that both types of equipment are needed. For example, a street railway repair shop is a good field for both kinds of driving. The blowers for the different forges are preferably driven in a group by a single motor, as are the wheel grinders, and possibly two or three of the lathes. Planers and drills, however, are often individually driven in the most advanced installations.

In one of the latest coffee and spice grinding plants, nearly all the grinders are driven in groups, as are the looms in a recent carpet mill installation run by induction motors. With alternating-current motors the speed changes are not as readily effected, but in the matter of operating, simplicity and low cost of maintenance, a first-class induction motor stands practically unequalled by any direct-current machine thus far built.

Small motors are now on the market which yield a remarkable performance in the way of reliable service, so that one need not fear excessive maintenance charges and costly interruptions, with the best makes. It would be difficult to name a more exacting service than the "body-ironer" of the laundry imposes upon a direct-connected motor. This machine is repeatedly reversed while running at full speed, and as these reversals sometimes occur every second, averaging 19 or 20 in the ironing of a single white shirt, the strain upon the motor is not difficult to appreciate. Yet motors are to-day in service driving such machines, and are constantly reversing from 600 r.p.m. + to 600 r.p.m., —, practically as fast as the operator can work the treadle, with comparatively little sparking, and every evidence of being able to keep up the pace for months to come.

There is ample opportunity to go to great lengths in testing and estimating the cost of each kind of drive in a given establishment, but it is a question how far such detailed calculations are profitable. Experienced judgment, reinforced by a few figures based upon the kind of service and the time occupied, seems to be the thing to fall back upon.

One thing that can be done to great advantage, however, is the accumulation of more data by engineers and manufacturers upon the amount of power required to operate different machines in specific service. Such data are so easily obtained by simple ammeter and voltmeter readings, and so readily noted down in connection with different speeds and cuts of machines, varying outputs and the like, that in time the engineering profession should be in possession of less incongruous figures than it now sometimes exhibits.

Unless the conditions of operation are known, it amounts to little to specify the power consumption of a given machine. Because one arrangement of linotype machine, for example, is operated by a $\frac{1}{4}$-H. P. motor, this by no means implies that all other linotypes are best run by that particular size of motor. The problems of motor driving are yet to be settled, in many cases, by the gathering of more complete data, and the exercise of broader judgment on the part of purchasers and their engineers.

THE DE LAVAL STEAM TURBINE IN AMERICA

APPLIED TO OTHER THAN ELECTRICAL APPARATUS

By John L. Mohun

THE pioneer work in connection with the introduction of the steam turbine in the United States is about over. Much has been accomplished since the year 1900, when the Westinghouse and De Laval companies first introduced their turbines, although one or two steam turbines had been imported before that date, the first being a 10-KW De Laval steam turbine dynamo, made by the Swedish De Laval Company and exhibited at the Chicago World's Fair in 1893, where it attracted considerable attention. This machine was afterwards purchased by Cornell University, where it was, until a short time ago, used in experimental research. On account of its historical value, however, the De Laval Steam Turbine Company, of Trenton, N. J., recently obtained possession of it. A comparison of this turbine, shown in Fig. 1 with De Laval turbines as turned out at present, shows that quite a little improvement has been made, although the machine in question is only about twelve years old.

As is well known, Europe was considerably in advance of America in de-

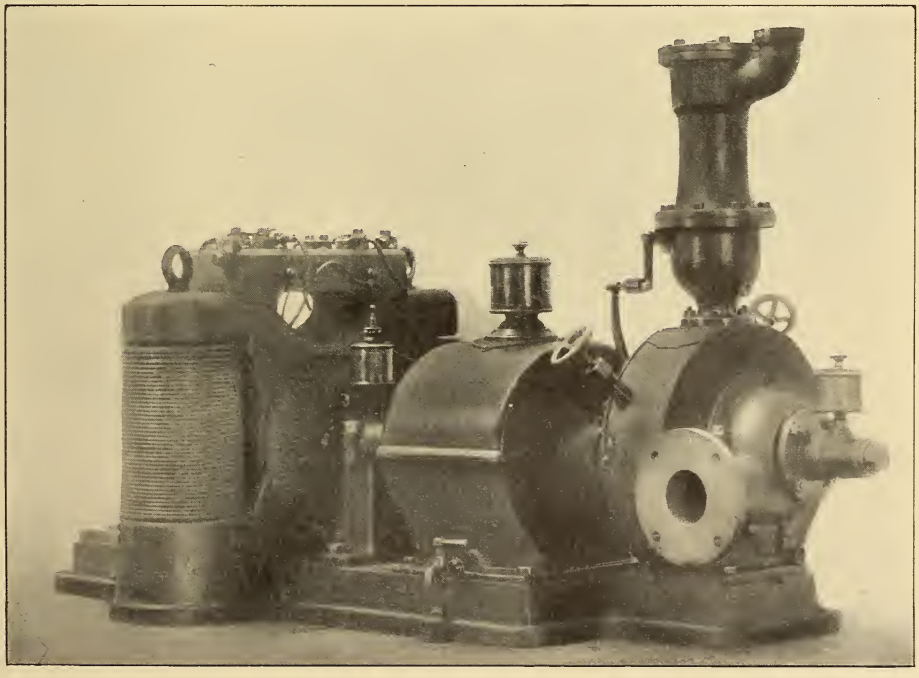


FIG. 1.—THE FIRST DE LAVAL STEAM TURBINE DYNAMO IN AMERICA. THIS WAS SHOWN AT THE CHICAGO EXPOSITION IN 1893

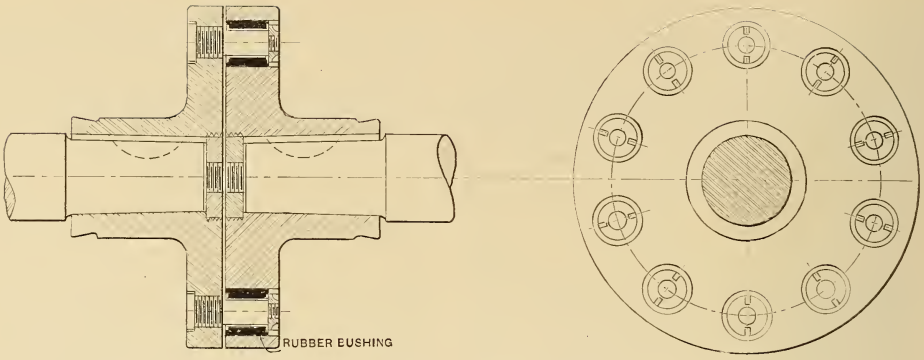


FIG. 2.—FLEXIBLE COUPLING FOR DIRECT DRIVING BY DE LAVAL TURBINES

veloping the steam turbine, the first commercially successful De Laval turbine being built in Sweden in 1882. It was shortly afterwards followed in Great Britain by the Parsons turbine, in 1884. This was due possibly to the a great deal has been written on the steam turbine, both of a technical and practical nature, but most of this literature has dealt with the application of the steam turbine for driving electrical apparatus. In this article will be

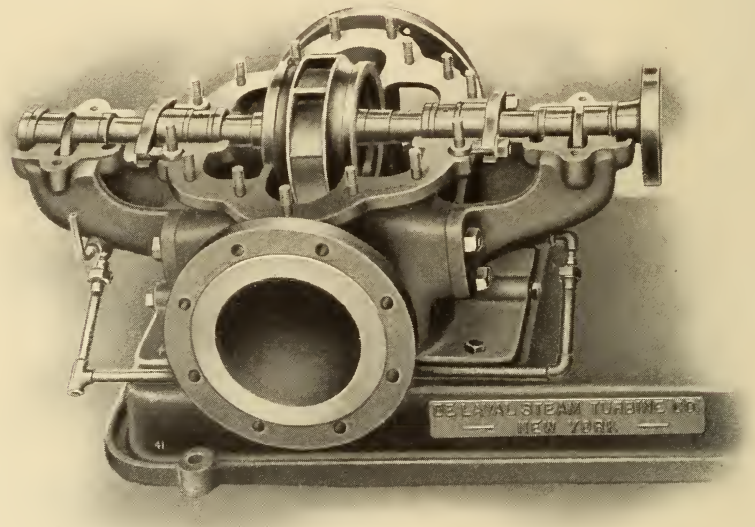


FIG. 3.—A SECTIONAL VIEW OF A DE LAVAL CENTRIFUGAL PUMP

high development which the Corliss engine had received at the hands of a number of manufacturers in the United States.

During the past two or three years recorded simply the progress which has been made in the use of steam turbines for direct connecting to other machinery than electrical.

The De Laval Steam Turbine Com-

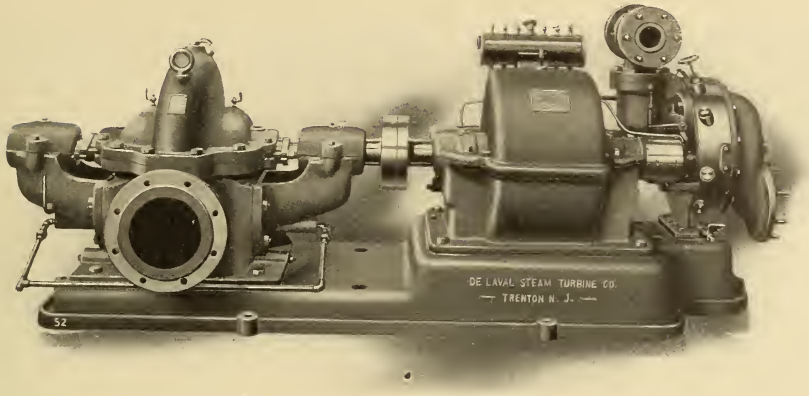


FIG. 4.—A SINGLE-GEARED DE LAVAL TURBINE PUMP

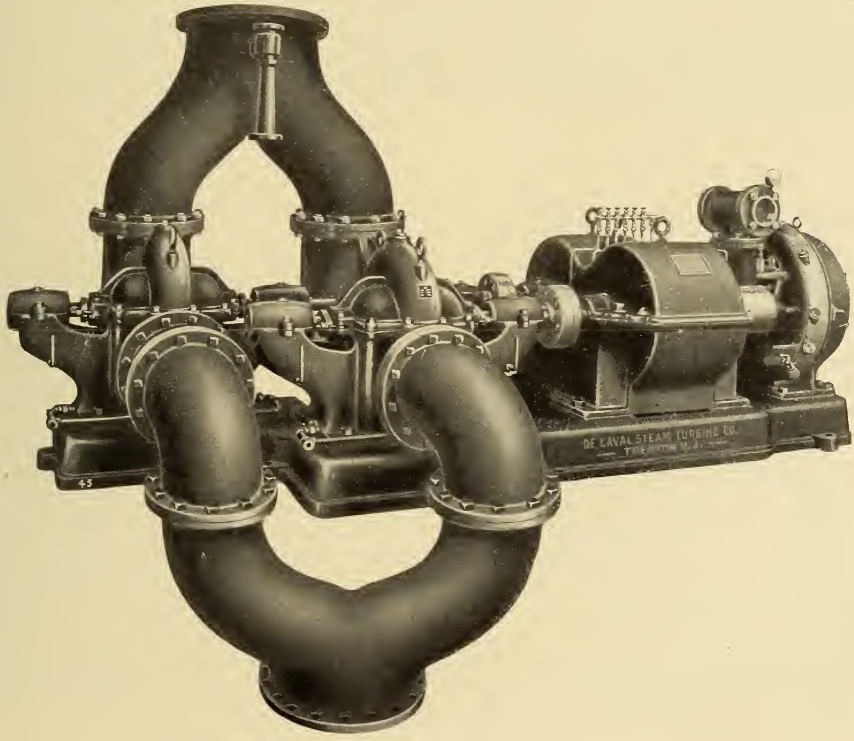
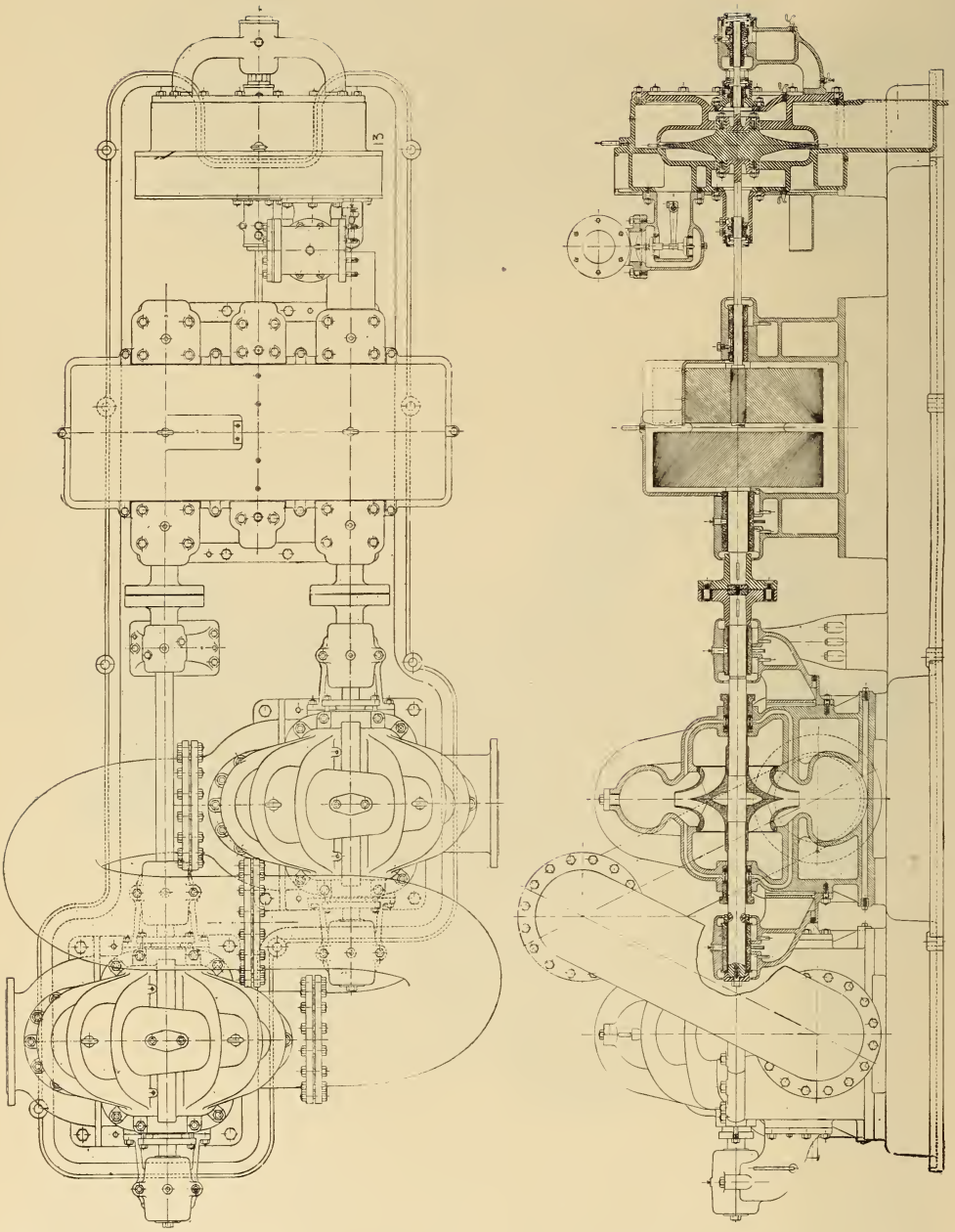


FIG. 5.—A SET OF DOUBLE-GEARED TURBINE PUMPS WORKING IN PARALLEL

pany are the only manufacturers of steam turbines in the United States who are applying their turbines for direct connecting to apparatus other than electrical generators. In Great Britain the Parsons turbine has been used to some extent in connection with air compressors and fans, and in France a number of Rateau turbines have been used for driving both centrifugal pumps and blowers. The foreign De Laval companies have also



FIGS. 6 AND 7.—A SET OF DOUBLE-GEARED TURBINE PUMPS COUPLED IN SERIES

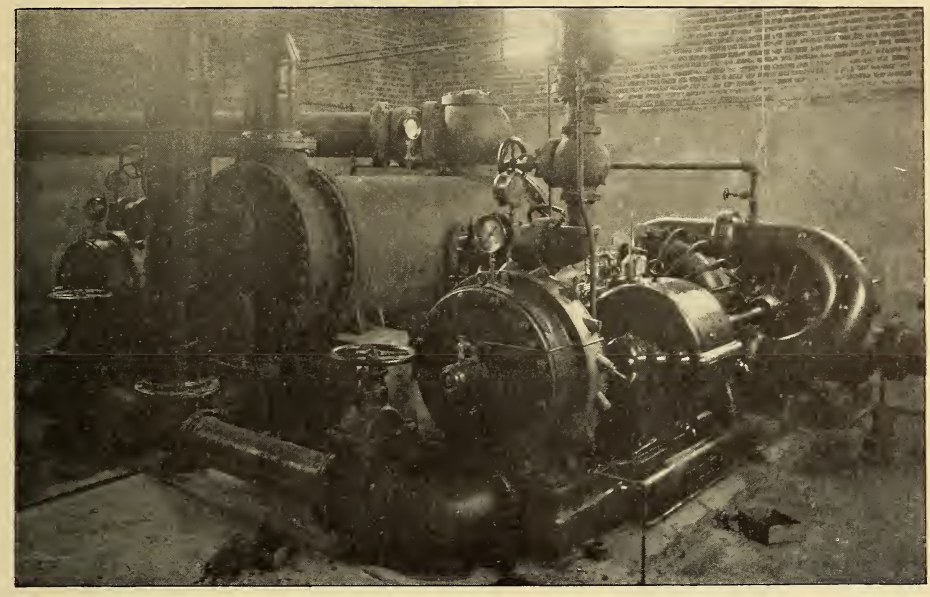


FIG. 8.—DOUBLE-GEARED SERIES-CONNECTED PUMPS FOR TOWN WATER WORKS SERVICE

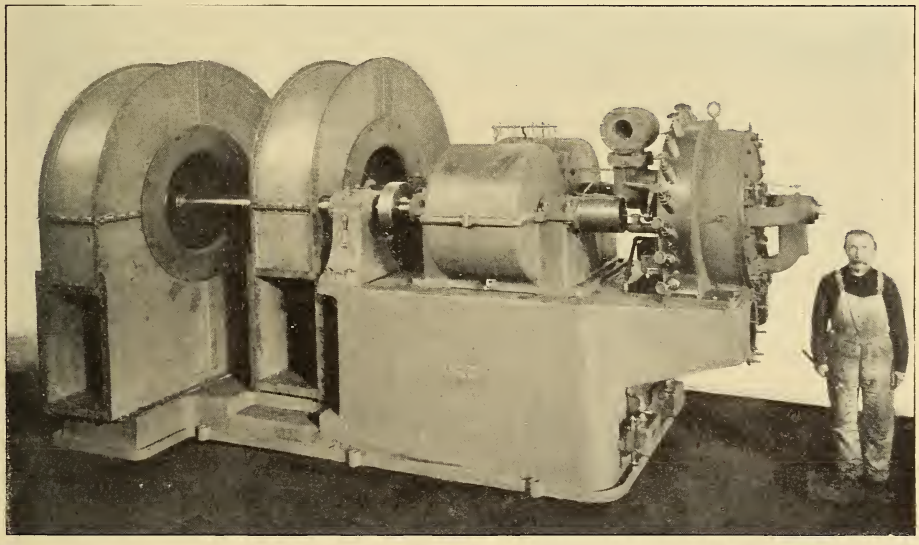


FIG. 9.—A SET OF 150-H. P. DE LAVAL SIROCCO BLOWERS. CAPACITY, 40,000 CUBIC FEET OF AIR PER MINUTE AT 21 INCHES WATER PRESSURE

built a large number of turbines for direct application to centrifugal pumps and blowers.

The most natural application of the steam turbine, outside of the electrical field, is for direct connecting to centrifugal pumps and blowers operating under moderate and high pressures. Because of the high speed of the turbine, both pump and blower impellers can be made to generate high pressures with less impeller diameter for a

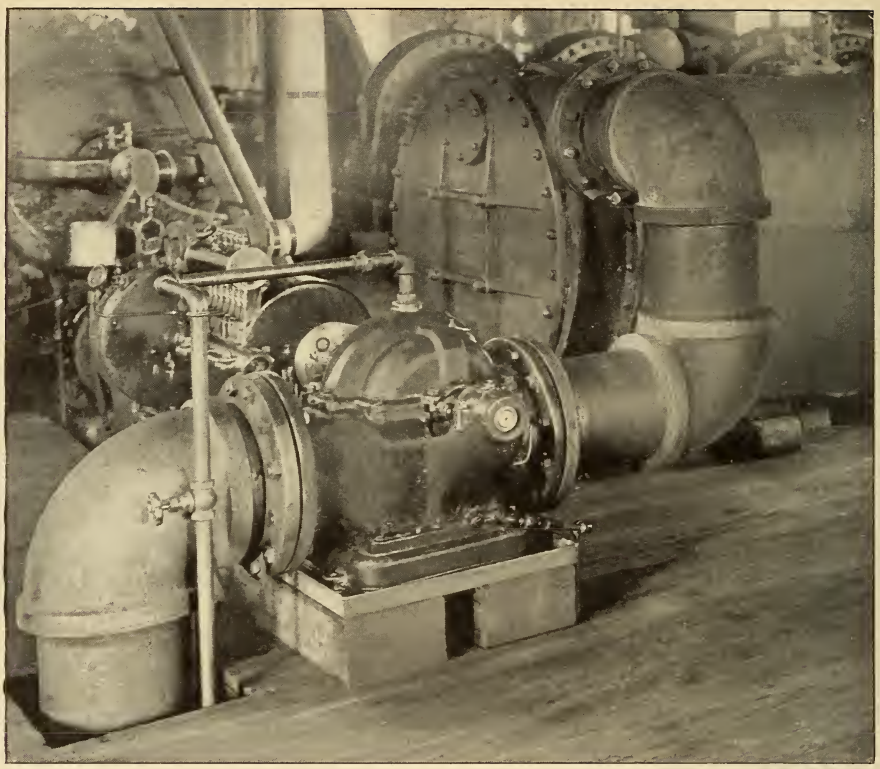


FIG. 10.—A SINGLE-GEARED TURBINE CIRCULATING PUMP FOR CONDENSER SERVICE

given capacity than was possible with the older, or slow-speed, machines. Thus the impeller friction is reduced, and the efficiency of the machine is correspondingly increased. Furthermore, a machine of this type is rotary throughout, and all reciprocating motion, and consequent vibrations, is done away with. On account of the entire unit being thus self-contained, heavy and expensive foundations are not necessary, and all that is required is sufficient foundation to properly support the machine.

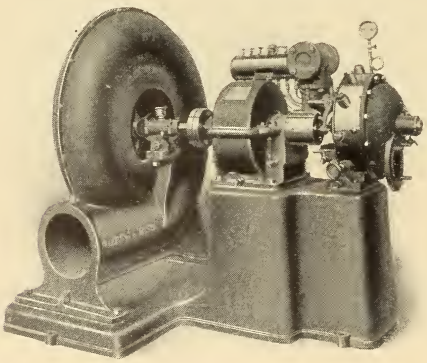


FIG. 11.—A DE LAVAL STURTEVANT BLOWER

The steam turbines used for driving centrifugal pumps and blowers are of the De Laval standard, and are the same in every respect as those used for operating electric generators. This is an impact turbine with a single turbine wheel, running at a high speed and carrying one row of buckets, against which the steam is delivered after having expanded completely in the nozzles. These turbine wheels run from 10,600 revolutions per minute, for the larger sizes, to 30,000 revolutions per minute for the smaller sizes. The speeds are reduced approximately 10 to 1, by helical gearing, giving driving shaft speeds of 900 revolutions per

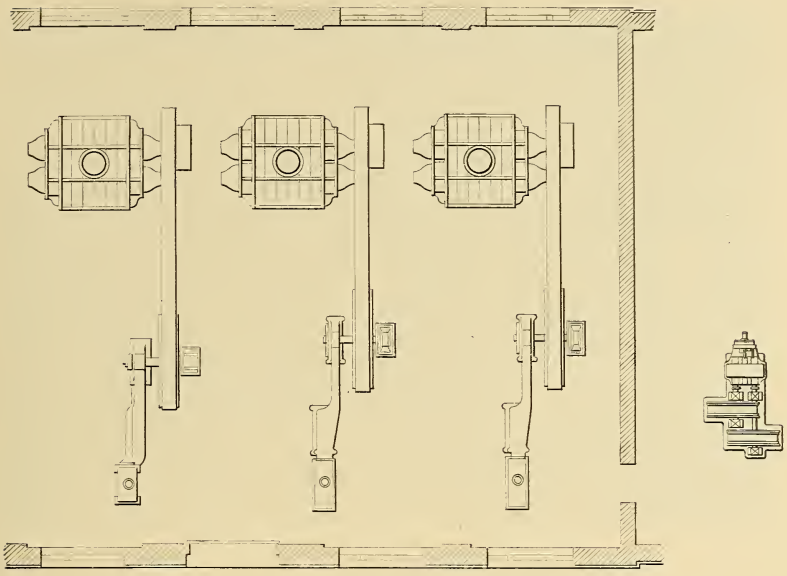


FIG. 12.—BLOWER PLANT AT THE PHILADELPHIA GAS WORKS. TOTAL CAPACITY OF THE THREE UNITS, 60,000 CUBIC FEET PER MINUTE. THE DE LAVAL STEAM TURBINE BLOWER SHOWN AT THE RIGHT, DRAWN TO THIS SAME SCALE, HAS A CAPACITY OF 30,000 CUBIC FEET PER MINUTE

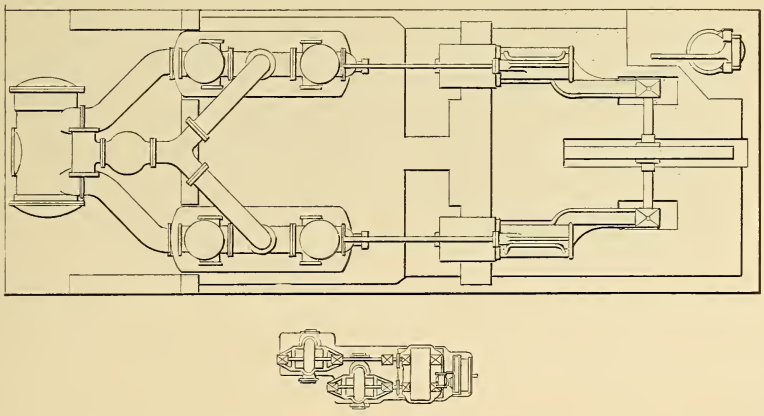


FIG. 13.—A CORLISS PUMPING ENGINE HANDLING 1800 GALLONS PER MINUTE AGAINST 110 FEET HEAD, COMPARED WITH A DE LAVAL STEAM TURBINE PUMP OF THE SAME CAPACITY. BOTH DIAGRAMS ARE DRAWN TO THE SAME SCALE

minute for the largest machines, and 3000 revolutions per minute for the smallest machines. A single gear is provided for turbines of from 7 to 55 H. P., and a double gear is used with turbines of larger size, ranging from 75 to 300 H. P.

The fact that their turbine was well adapted for this class of work was fully appreciated by the De Laval Company, and they, therefore, several years ago, developed a line of centrifugal pumps and blowers especially suited for direct connection to their high-speed turbines. These machines are mounted on a common bedplate,

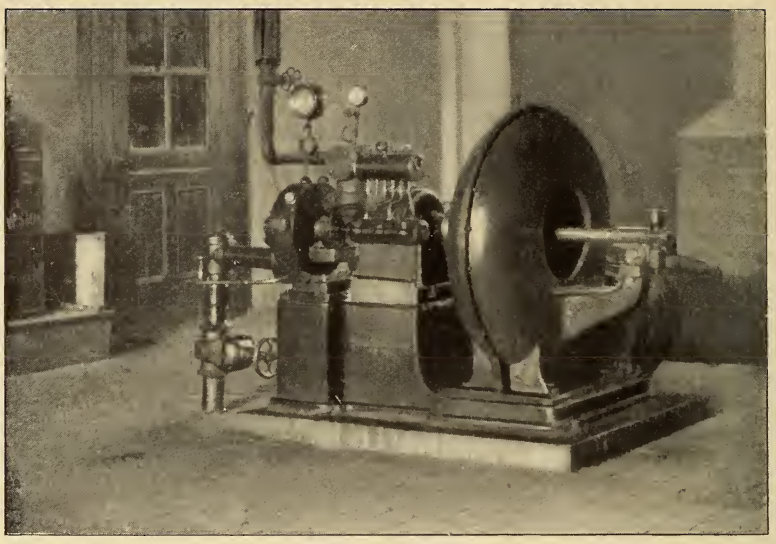


FIG. 14.—A GAS WORKS TURBINE-DRIVEN BLOWER

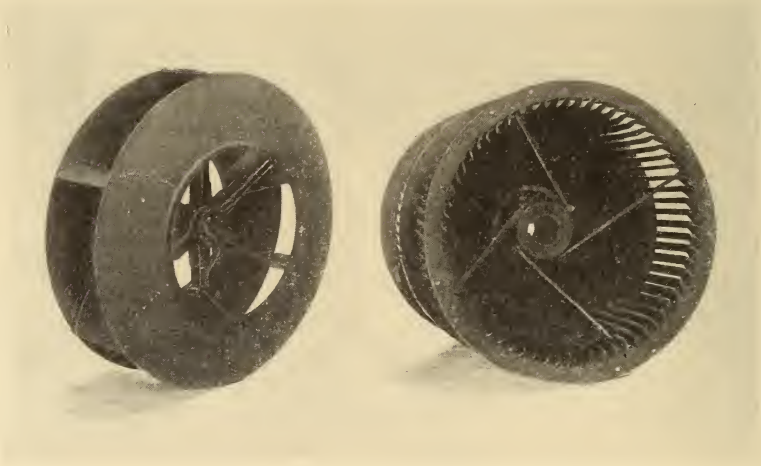


FIG. 15.—STURTEVANT AND SIROCCO BLOWER IMPELLERS

of box type, with strengthening ribs in both directions. The bedplate is provided with an oil groove running entirely around it.

The turbines and the machines are directly connected by flexible couplings, the details of which are shown in Fig. 2. The metal disc of this coupling is fastened to the shaft by Woodruff key, taper fit, and countersunk nut. The two discs are bolted together by steel countersunk bolts and nuts. These bolts are fastened in one of the discs. In the other disc are mounted rubber bushings lined with a steel tubing, through which the bolts pass. The discs are placed slightly apart. This, and the rubber bushings, permit of any slight irregularity in the alignment of the two machines. The rubber bushings also reduce the effect of any shock on the turbine which may be developed in the machines.

PUMPS

Fig. 3 illustrates the general design of the De Laval centrifugal pumps; also the construction of the impeller, bearings and packings. The pump case is horizantally divided through the centre of the main shaft, thus permitting a free examination of all the working parts when the pump case cover is removed. The bearings are of the ring-oil type, and are independent of the shaft packings, preventing the shaft and runner from getting out of alignment through wear. The impeller is usually made of bronze. It is of the "shrouded" type, and is designed for the particular service conditions under which it is to operate. The water enters the impeller near the centre on each side, thus preventing end thrust.

The single-geared pumps have capacities from 80 to 4400 gallons per minute, at lifts ranging from 30 to 180 feet. An example of this type of pump is given in Fig. 4, which has a capacity of 1700 gallons per minute at 100 feet head.

The cases of the double-geared pumps are staggered on the bedplate. This permits them to be operated either in series or parallel simply by changing the pipe connections. When operated in series, as in Figs. 6 and 7, they will handle one-half less water, at double the head, than when operated in parallel as shown by Fig. 5. This results in a flexible arrangement. The capacities of these pumps are from 775 to 26,000 gallons per minute, with heads varying from 30 to 300 feet. These two classes of pumps are built for meeting all usual pumping conditions. They are also actually handling heavy liquids, sewage, etc.

Fig. 16 illustrates a high-pressure pump built in various sizes, with lifts ranging from 300 to 600 feet, handling from 200 to 2000 gallons per minute. This is a series-connected pump, with a small high-speed impeller direct-connected to the turbine shaft, and a large low-speed impeller direct-connected to the geared shaft. The low-speed impeller lifts the water and passes it, under pressure, to the high-speed impeller. These pumps are particularly suited for boiler feed and elevator service.

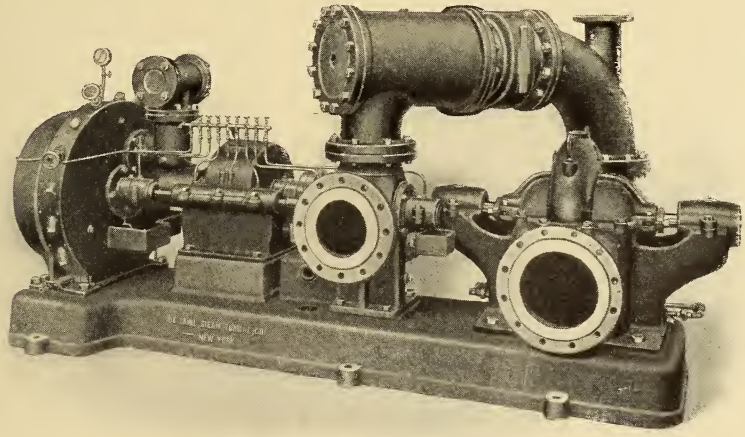


FIG. 16.—A SET OF SERIES-CONNECTED TURBINE-DRIVEN HIGH-PRESSURE PUMPS

Fig. 10 shows a single-geared pump of 55 H. P., used for circulating water in connection with a condenser. In Fig. 8 is shown the arrangement of piping, condenser, etc., of a couple of

double-geared pumps of 110 H. P., the pump cases of which are connected in series. These machines are used in connection with a town water works. Each of them will deliver 1250 gallons per minute against a total head of 250 feet, but in order to provide fire protection for the town the piping is so arranged that both units can be run in series, and deliver 1250 gallons per minute against 500 feet total head.

Fig. 13 illustrates, in diagram form, the great advantages as regards saving in floor space which it is possible to obtain by the use of centrifugal pumps operating at high speed. Besides the smaller floor area needed, there is a great saving in foundations.

BLOWERS

On the single-geared turbines the Sturtevant type blowers are generally used; above that size, blowers of the Sirocco make are usually employed. Fig. 15 shows the difference in the impellers of the Sturtevant and Sirocco blowers. The Sturtevant impeller is composed of a comparatively small number of blades, which are slightly curved in a direction opposite to that in which the impeller revolves. The impeller is of the "enclosed" type.

The Sirocco impeller is made up of a large number of small blades, curved in the same direction as that in which the impeller revolves. The centres are made of steel castings, and the blades for the larger machines are made of sheet aluminium, so as to reduce the weight at the periphery as much as possible.

The Sturtevant blowers used for this purpose are of a special type, on account of the high speed at which they run. The casing is of cast iron and is of the usual design. The casing of the Sirocco blower is of sheet steel construction. The intake flange is of cast iron and is designed so as to offer as little resistance as possible to the inflow of the air. Fig. 11 illustrates a 20-H. P. De Laval steam turbine direc tconnected to a Sturtevant blower.

In connection with the double-geared machines, the blowers are staggered the same as with the double-geared pumps. The shaft for the

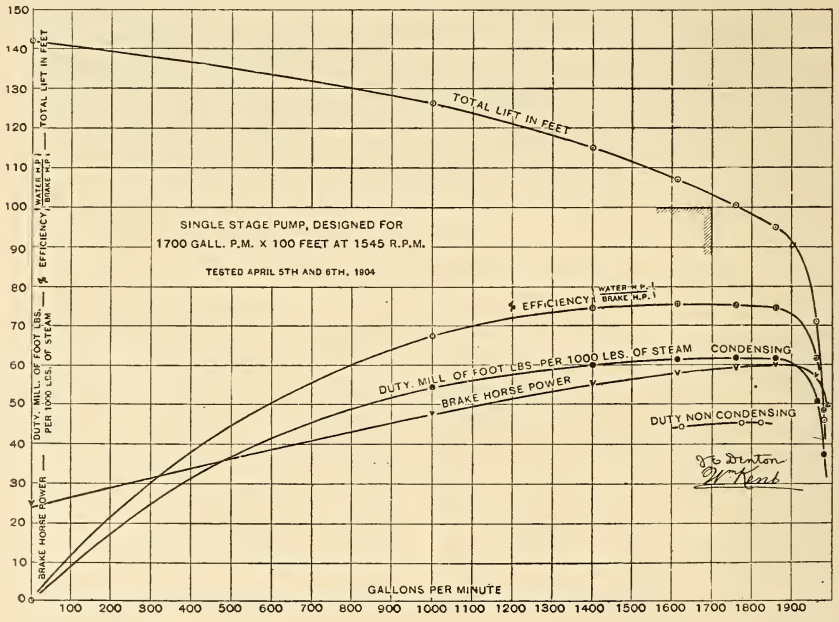


FIG. 17.—TEST DIAGRAMS FOR A SINGLE-GEARED TURBINE PUMP

outer blower passes through the casing of the first blower, just clearing the wheel. A blower of this type is illustrated in Fig. 9. This machine has a capacity of 40,000 cubic feet of free air per minute, while maintaining a pressure of 21-inch water gauge.

Machines of both these types have been used to a considerable extent in gas works. In the manufacturing of coal gas two are usually installed in a plant, running alternately for five or six minutes at a time. The steam pipe connection is equipped with a small by-pass which furnishes steam enough to keep the turbine just running. The blower is thus never entirely shut down. This arrangement minimises the shock when the throttle is fully opened, and the entire load thrown on.

Fig. 14 shows a 10-H. P. turbine blower in this service.

Fig. 12 shows a comparison of an existing blower plant having a capacity of 60,000 cubic feet of free air per minute against 21-inch water gauge, with a De Laval steam turbine blower set having a capacity of 30,000 cubic feet of free air per minute against 21-inch water gauge, both being drawn to the same scale. This well illustrates the saving in floor area and foundations by the use of high-speed machinery of this kind. Besides, the turbine blower is just as efficient as the more cumbersome engines and blowers.

In conclusion, the diagrams represented in Figs. 17 and 18 may prove interesting. The former gives the results of tests of a single-geared pump of the type illustrated in Fig. 4, showing an efficiency of 76 per cent.

Fig. 18 similarly gives test results obtained by the same investigators, Professors J. E. Denton and William Kent, with a series-connected turbine-driven high-pressure pump like that shown in Fig. 16.

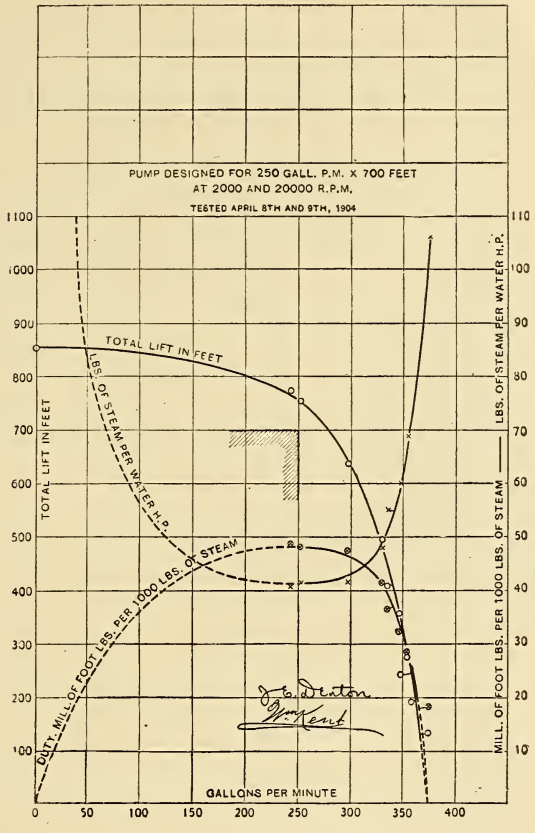
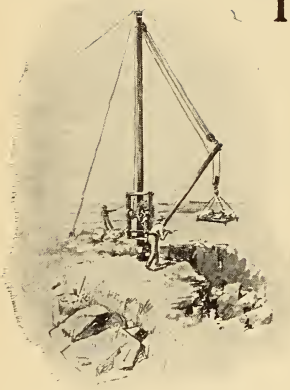

PUMP DESIGNED FOR 250 GALL. P.M. x 700 FEET
AT 2000 AND 20000 R.P.M.
TESTED APRIL 8TH AND 9TH, 1904
TOTAL LIFT IN FEET
LBS. OF STEAM PER WATER H.P.
LBS. OF STEAM
DUTY, MILL. OF FOOT LBS. PER 1000 LBS. OF STEAM
TOTAL LIFT IN FEET
LBS. OF STEAM PER WATER H.P.
MILL. OF FOOT LBS. PER 1000 LBS. OF STEAM
GALLONS PER MINUTE
J. E. Denton
Wm. Kent

FIG. 18.—TEST DIAGRAMS FOR THE PUMP SHOWN IN FIG. 16

NOTES ON STONE MASONRY

By Charles Arthur Hague



THE science and art of producing proper masonry structures for certain parts of water works plants, consist in so adjusting the costs and conditions as to build a monolithic mass of acceptable quality, and at the lowest practicable cost per cubic yard. In some cases it will pay to dress the stones considerably, even in rubble work, so as to have somewhat more regular and uniform joints and beds and thus save mortar where sand and cement are expensive, and stone is cheap.

The writer has recently finished some reservoir work situated about six miles from the nearest railroad station, but where the stone is found in plenty at the site, and where sand and cement have to be hauled the six miles from the railroad. The stone is very cheap and the mortar is dear, so that in such a situation it will pay to use some labour upon stone and save the mortar so far as possible. In another case, expensive stone demands the utmost economy in that material, and permits a more lavish use of mortar.

It is a matter of experience and judgment, and a good sharp contractor will sometimes appear in his bid to be very low in his figures for good work; but at the finish he will be found to have cleverly balanced up the different factors in the situation, and be really better off for actual profit than one with considerably higher figures, but having devoted much less intelligent thought to the details of construction, handling and transportation.

If labour should be high, then the materials would be sacrificed all around, so to speak, in the best manner to economise the labour.

The question, therefore, of how much hammering or dressing to do on a stone before setting it in construction, is largely a question of relative cost between labour, stone and mortar. But with the best of intentions upon the part of a stone mason, it will be found to be rather difficult for him to resist the hammering of stones, as he has a confirmed habit of giving them a whack or two even when such stones are exactly right. The writer has arrived at the conclusion that it is physically and mentally impossible for a stone mason to let a stone get by him without a thump or two with his hammer, sometimes apparently for no other reason than to show the superiority of mind over matter, or mortar.

Although as a general principle it will at most times be better to place the work under contract, guarded by competent specifications and rationally but rigidly supervised, in extensive and complicated work it certainly at times seems preferable to divide the quantities up so as to do by days' work some of the portions where the engineer and those in authority feel that the actual and exact quality involves important considerations beyond any question of mere price. Indeed now and again cases are met with in regular practice in which it might very easily be less costly to have the work done by the day, than to give it to a contractor under uncertainties which would justify him in making allowances for wide leeway in his prices so as to meet possible contingencies that

might never arise. Such particular portions of the work may not be a large portion of the whole, but may form, as it were, the pivot upon which the success of the entire work turns.

Contractors are only human after all, and are made to feel many times, no doubt, that competition pinches them down to the lowest possible price; hence, in a sort of false logic they assume that they are entitled to all privileges which make towards scalping all they are able to out of the job. The real ingeniousness, apparent ingeniousness, and altogether child-like blandness, with which they discover points claimed as not covered by the specifications, approach the marvelous.

Some contractors take work so low that it is really impossible to get through strictly under the specifications; and hence sometimes occur endless disputes and final suspension of work. Sometimes the contractors are warlike and persistent in dodging specifications, and then there is only one simple effective remedy, and that is the stoppage of estimates for payment by the engineer. There is no use in arguing with persistently obstinate contractors bent upon avoiding certain clauses in the specifications; the method just mentioned will be found effective and fairly prompt in its results.

It goes without saying, that all work ought to be done as well and as perfectly as human effort can accomplish, but at times no doubt practical difficulties involving certain weak spots in human nature result in bringing about the every-day methods we see about us; these, a reasonable hopefulness can lead us to think may be improved upon as a higher wisdom political and otherwise will continue to teach that a straight line is the best to follow, and the axiom may finally be evolved that it actually pays all concerned to have the work done well.

There is probably no kind of work connected with a water works plant which requires more faithful labour or more persistent, careful watchfulness during construction than stone masonry. Not only with what may be called fine or close work, but also with the rougher kind of rubble work. The rough, coarse, thick-jointed rubble work sometimes required and preferred, fills a certain place much better than cut stone work possibly can. It will pay to think over the matter of masonry, and it will be found by a little experience that there can just as well be had adequate and satisfactory work, and have it economically built, as to put up with some of the feeble imitations of stone work so often found here and there.

Portland cement mortar only should be used about hydraulic work. The writer prefers the American Portland cement for several good reasons, although he has used both this and other brands on the same piece of work with no practicable difference apparent either during the work or after extremely severe service in actual use of the structure,—in one case a masonry dam exposed to heavy floods and ice.

In any event, the engineer in charge of the work should absolutely control the brand and quality of the cement, but the choice of brand is not to be so closely drawn that the contractor should be forced to suffer hardship in the matter of price, in case a favoured manufacturer takes advantage of the specifications calling for his particular make of cement. The engineer is really an independent arbitrator under the contract; and, although it is his duty to see that the party paying for the work is not imposed upon, nevertheless he should not permit the contractor to be wronged in the premises.

In carrying out a contract for stone work to be done about the intake and wet wells of pumping machinery and pumping stations, for water wheel intakes and bulkhead walls, for stone dams, and for reservoir masonry, there is often great difficulty in obtaining from contractors for such work the proper quality of materials and workmanship. And this is really not from any effort to be unfair par-

ticularly on the part of the contractor, but mostly because contractors as a rule are apt to think that an ordinary cellar wall sort of construction will answer for the purpose in view, and do not appreciate the difference between simply sustaining weight and the requirements of holding or retaining water.

Stonework, when completed for the purpose of retaining or withstanding water, must be one solid, continuous, impervious mass, with all spaces completely filled with stone and mortar; and this, although beautifully simple and effective when built, seems to be obtained only by the most earnest and oftentimes apparently despotic supervision upon the part of the engineer or his assistants and inspectors. The proper kind of work can be done, and, as a matter of fact, is no more difficult of accomplishment than open and poorly put-up work. The whole trouble seems to be that the working masons, when first undertaking such work, do not clearly comprehend exactly what is wanted, and what the conditions are that are to be met.

The great majority of heavy stone masonry is for foundations pure and simple, where immense weights are to be supported regardless of anything else, and in which a solid and immovable bed for the stone is desirable without regard to imperviousness to water. A solid and stable contact of the members of a wall being much more important than anything else, of course renders thick mortar joints objectionable.

With a "water wall," however, the demands are entirely different,—in fact, so different that the competent mason who thoroughly knows the science and art of his trade, is apt to think that an engineer is a "crank" and entirely ignorant of the first thing about mason work when something is insisted upon out of the usual foundation building line. Doing the work the right way is not materially different from doing it the wrong way so far as the amount of labour is concerned. But in case of a foundation for superimposed weight, a flat or approximately flat bed, substantially supported and with sufficient mortar to ensure a good bearing, is all that is needed, the striking of the outer joints with mortar not being necessary. In the case of the "water wall," however, the absolute and complete bedding of stone in full mortar beds, perfectly filling all of the under space with mortar is far more important than the securing of any sort of solid touch with the stone beneath.

It will be observed that nearly all masonry for water works purposes is comparatively limited in height and not called upon to bear any great burdens so far as downward pressure is concerned; therefore in a water wall, a considerable thickness of mortar is not objectionable in most cases,—in fact a mortar bed or joint must be of sufficient thickness to ensure the practicable manipulation of the materials so that it may be certainly known that all spaces are really and actually filled.

Further than this with the water wall, all outside joints must be filled and struck so as to completely shut off all outer openings between the stones, and then the inner joints between the stones within the body of the wall must be filled or slushed with mortar just thin enough to find and fill every crevice. And in carrying out this idea it is far better to have the inner joints sufficiently open, say from two to four inches, to remove all difficulties or uncertainties of their filling, than to endeavour to make such joints of impracticable closeness and so defeat the prime requisite of the undertaking.

Under appropriate conditions there are no objections whatever to leaving very liberal inner joints, which, after being partially filled with slush mortar, are filled nearly full of spalls or crushed stone, the displacement of the mortar filling the space to the top of the course. The setting of the cement in such work will produce a monolithic construction, but the mistake must not be made of putting in the spalls or crushed stone and then attempt to flush with thin mortar, as it is hardly

possible for human skill and application under such circumstances to escape serious consequences on account of the all but insurmountable difficulty of completely slushing the packed-in spalls or stone in all of their interstices. It is easy to displace thin mortar by putting in spalls, but very difficult to flow thin mortar amongst spalls and the like.

By a little study it will be readily seen then, that the operation of building a water-tight wall consists in having all of the stones actually and fully bedded in mortar clear across the wall, the outer joints filled, and then the inner joints slushed or trowelled full of mortar. The result of this will be that each course as laid will be perfectly solid clear through the wall, and when the work is finished it will be one continuous impervious mass, unbroken and unchecked throughout its length, breadth and thickness.

The expression of laying the work in courses is implied in the foregoing, but the upper surfaces of the work should always be kept as rough as possible so as to give not only a firm hold to the succeeding masonry, but as well to prevent all tendency towards easy lines for the water to find and follow. Water is so perfectly mobile, and so completely susceptible to the laws of gravitation, that the utmost care and skill are necessary to keep it in its place when the attempt is made to impound or to convey this common but most necessary fluid.

Masons can just as well be taught to build a wall in the proper way as in the usual manner of putting a few inches of mortar bed beneath the outer edges of the stones, and then blocking up the inner portions with spalls, thus leaving most of the stone's bed empty, dry, and useless so far as a wall for retaining water is concerned. Of course mason work cannot be too good; but it might be extravagant. First-class workmanship put into rubble walls, with adequate beds and joints, will produce immeasurably better results in a water wall than closely cut and jointed work. If finely cut beds and joints are used, they will have to be separated at any rate far enough to ensure the complete filling, and the chances of a rough bed and joint making an impervious monolith are much greater. In fact, properly laid rubble is far better than badly laid cut stone with beds and joints imperfectly filled with mortar.

One should take pains enough with the workmen to explain to them the kind of work wanted, and any man with enough intelligence and skill to hold his job as a mason will be found to be fully capable of giving the work desired, provided you know what you want and make him feel that you do. The working masons are paid by the hour or day generally, and aside from temporarily changing long acquired habits of setting stone they can just as well work one way as another; many masons after being driven from their habits of ordinary wall work, find it quite as handy to build a good water wall and with no more actual labor per unit of length.

It is easier work to build a water wall properly than badly, for the simple reason that in making a full mortar bed under a stone, the stone is just floated to its place in mortar without regard to any special points of contact with the stone underneath. Of course some of the points touch, but if left alone after being floated into place and pounded lightly, the stone will not swing or move, and when the mortar sets, a perfect bed will result. Then if sufficient space has been left to easily put in the interior vertical joints, the stone setting can be accomplished rapidly and well. The chief person with a grievance under such circumstances will be the careless contractor who did not figure upon the amount of mortar necessary for this "floating" and "bedding" process, but he will either have to take his medicine or the engineer's inspector will have a bad wall.

Anyone who will carefully watch a stone or brick mason at work will soon become convinced that the building of masonry is an art in the highest

sense of the word; the bringing of the work up to an actual line and level in all its parts being little short of slight-of-hand, considering the apparently rough methods of wooden straightedges and ordinary wooden cased levels. But there are thousands and thousands of stone masons and stone cutters who will bring a long coping on top of an elaborate piece of work up to a stage of perfection in alinement and level, in which the engineer's level will fail to detect any inaccuracies.

The wooden straightedge and level depend upon the same principles as the most elegant and accurate leveling instrument extant, and the stone cutter or mason with clear brain and true eye can obtain as fine drawn results with his clumsy looking straightedge and bedraggled, indented level, as the most skillful engineer can with his telescope and cross hairs. It is a question of knowing how and of skill, rather than a choice of tools.

When one looks at the rough instruments and the little posts set upon spots cut on the surface of the stonework, from and to which the long shaky straightedge is shifted and reversed many times, the impression is apt to be that the weight of skill is not altogether with the engineer.

But with all the mason's skill in doing the work, the engineer leads him a long way in determining the quality and kind of construction necessary for the retention of water under pressure.

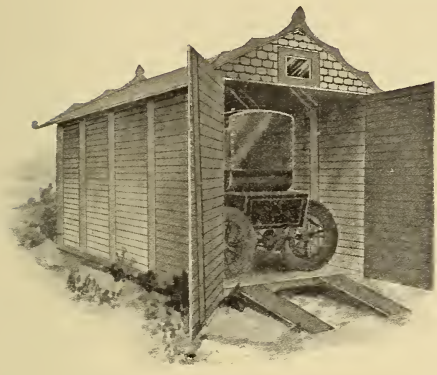
Granting, then, that the stone masons have the requisite brains and skill, and most of them certainly have, a long step in the right direction will have been taken when a clear understanding and purpose of the work are clearly laid before the contractor and the men who actually do the work, and it will pay to put in a little time in this direction. No matter how carefully the specifications may be drawn, just as soon as the work has been let and the contract signed, it seems to be the habit of the average contractor to act as though he had never read a word of the specifications or seen a single line of the plans.

In bidding on masonry, most contractors apparently act upon their preconceived ideas, whatever such ideas of masonry may be, utterly regardless of the directions laid down in the contract. The labour then devolves upon the inspectors of the work to make life a burden to the contractor, the contractor's men, and the inspector himself,—and all this simply to secure and insure to the party paying for the work, a common sense and fairly equitable return for the money laid out.

The main cause of trouble comes from the failure of the contractor, and the masons laying the stone, to recognise that merely stability against the downward pressure upon a loaded foundation is not the same thing as imperviousness to water and resistance to being overthrown.

THE UTILITY OF PORTABLE BUILDINGS

By Arthur Fage



A 9½ X 16-FOOT PORTABLE AUTOMOBILE HOUSE, BUILT BY THE MERSHON & MORLEY CO., SAGINAW, MICHIGAN, U. S. A.

IN this short article the writer proposes to deal with the subject of portable buildings, with their relationship towards actual utility, generally, from an engineering point of view, and for their use as dwellings and other purposes. In any great outdoor engineering work, it would be impossible to commence operations within a reasonable period unless some means were obtainable to construct and build on the spot a group of buildings in which, and from which, the organization could be operated and promoted.

The class of building under consideration doubtless lends itself to the necessary simplicity, rapidity of construction and economy in cost. As a case in point, the writer has in mind a large water scheme now in progress, where the dams, reservoirs, and other complicated works have to be carried out at points miles away from the nearest towns and villages.

The board representing the various towns concerned, and who have this work in hand, have caused to be built a by no means small village, comprising whole streets of workmen's houses, with shops for various tradesmen, a large recreation hall, hospital, church, in fact all the accommodation necessary for the comfort and sociability of a community called together for a special and common purpose. All of these buildings have been constructed of timber and corrugated iron. Had they been built of brick or stone, the time required for their completion would have been an item for serious consideration, whilst the transit of such a quantity of material, at a time when railway communication was not in existence, would have been both laborious and costly. The buildings decided upon, however, were quickly made and the material, being easily transportable and of a light character, reduced such objections to a minimum. They will no doubt have a ready sale when their purpose has been fulfilled.

Again, in the construction of any large railway, passing, as it most frequently does, through rough and open country, a similar method of accommodation to that just described is most commonly adopted at any isolated positions which may demand it. For camping purposes, whether it be for volunteers taking their annual course of training, or for other branches of the military service, buildings of this description have been found to be useful and efficient. This is evidenced also by the fact that the British War Office has erected many such quarters on Salisbury Plain and at other centers where manoeuvres are from time to time in progress.

Coming to the efficacy of these buildings purely as places of abode,

A ROW OF CORRUGATED IRON WORKINGMEN'S HOUSES ERECTED BY MESSRS. BRUCE & STILL, LTD., LIVERPOOL

A CRICKET PAVILION ERECTED AT WINCHESTER, BY MESSRS. HARRISON SMITH & CO., BIRMINGHAM

those who have bungalows constructed in this way in some secluded spot in the country, to which they fly at "weekends" and on other favourable opportunities for quietness and rest, no doubt have pleasant views on the subject; or others who may be familiar with their use as shooing boxes, and so a centre of sociability after a successful day, will no doubt appreciate them.

This class of building may be ornate and tasteful in treatment and decoration, and also can be ventilated and heated in a satisfactory manner. If built up a few feet from the ground on short columns or piles, more especially if the site be marshy or damp, no fear need be entertained because of such location.

As a tenant's fixture, if bolted to brick foundations, in which case the fire-places and chimney breasts may also be built up in brick-work, the building can at any future time be lifted off and moved when required.

In tropical countries portable buildings are largely used as dwellings, stores, warehouses, etc. Without them, the discomforts and inconveniences of a hot climate to one not accustomed to it, would be almost unendurable. Speaking generally, there is apparently every indication that portable buildings have come to stay.

The wide range of character of portable houses as at present turned out by different builders is perhaps best indicated by the range of prices. This is from about $25 (£5) to $15,000 (£3000), the former being one builder's quotation for a cycle shed, and the latter for a 48-room hotel for the tropics. Between these extremes there is a great variety of workmen's cottages, club houses, construction gang houses and the like.

Both wood and iron are the materials used in building them, but wood, generally speaking, is preferable, though the wooden house runs a bit higher in first cost than the other. The specifications for the houses, as put out by several well-known builders, are suggestive of their principal characteristics.

Messrs. Harrison Smith & Com-

A PAVILION BY MESSRS. BRUCE & STILL., LTD., LIVERPOOL

A GOLF CLUB HOUSE ERECTED BY MESSRS. BRUCE & STILL, LTD

pany, for example, of Birmingham, and Messrs. Browne & Lilly, Ltd., of Reading, England, both of whom have done considerable work along these lines, give the following data :—

Walls.—Constructed of strong deal framing, mortised and tenoned together and covered on the outside with sheet felt and rustic weather-boarding and part match-boarding and overlays, or 24-gauge galvanized iron, according to design, and lined with match-boarding inside.

Partitions.—Match-boarded both sides.

Doors.—Four paneled, moulded both sides, fitted with strong hinges and good lock and suitable furniture.

Windows.—Oval moulded casements, about 18 inches wide, glazed with 21-oz. sheet glass, casements that open, fitted with set open and casement fasteners.

Mouldings.—Moulds fitted to all doors and windows, and all rooms fitted with skirting and cornice moulds.

Flooring.—Sleeper plates and joists and $\frac{7}{8}$-inch T. & G. flooring boards.

Ceilings.—Match-boarded at about 10 feet from the floor, and when beneath roof, felted as well.

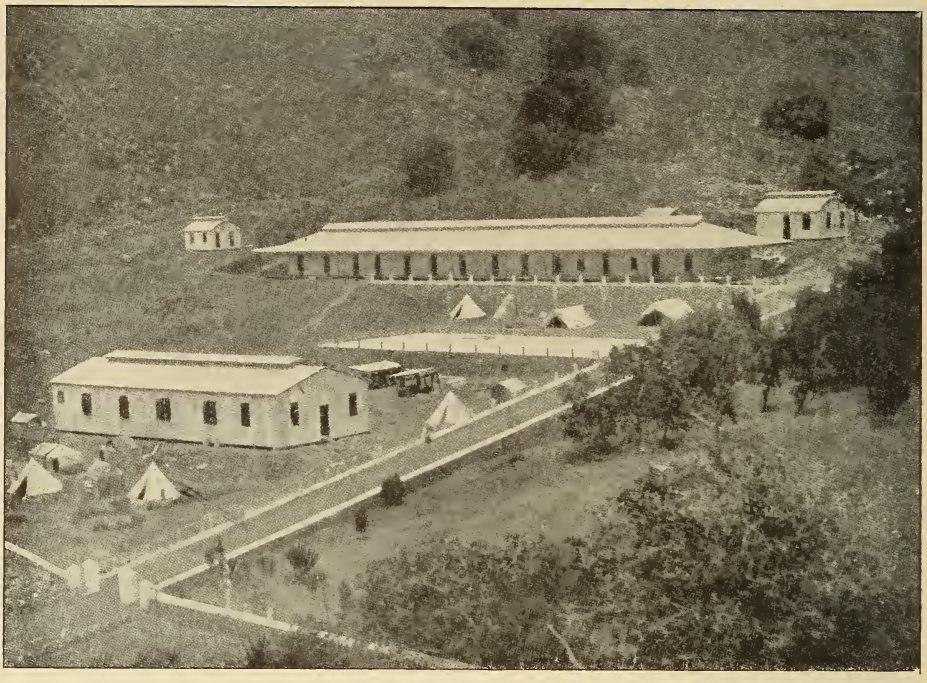
Roof.—Constructed of strong principals and purlins, covered on the outside with 24-gauge galvanized iron, and lined with sheet felt and match-boarding, gutters to eaves and down spouts to ground, barge boards and finials to gables. If the roof is covered with tiles instead of iron, a stronger roof is prepared. Roofs prepared for thatching are match-boarded and lined with water-proof felt, and covered with 8-inch heather thatch.

A SIX-ROOM PORTABLE COTTAGE BUILT BY THE MERSHON & MORLEY CO., SAGINAW, MICH., U. S. A. SIZE 12 FEET 8 INCHES WIDE, 41 FEET LONG, AND 7½-FOOT SIDE WALLS

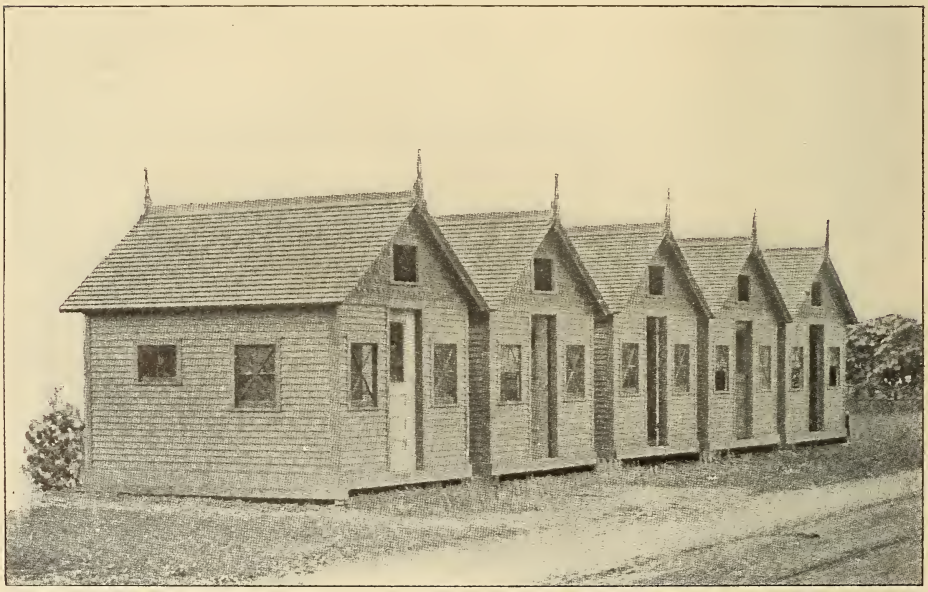
Finish.—All outside woodwork and un-galvanized iron work painted three coats, inside boarding sized, stained and varnished one coat.

Foundations.—Brickwork recommended. The builders supply plans and give every assistance to obtain local tenders for same, but if the ground is firm, clear and level, creosoted sleeper plates answer equally as well and are much cheaper.

Many people take it for granted that a portable house is necessarily a light and flimsy thing, with little more protection against the weather than is offered by a good tent. While this may have been true to some extent in the early days of the art of building them, it not true to-day. Thus the Mershon & Morley Company, of Saginaw, Mich., one of several well-known American portable house builders, ex-



GALVANIZED IRON BUILDINGS ERECTED IN ST. HELENA BY MESSRS. F. MORTON & CO., GARSTON, LIVERPOOL, FOR THE BOER PRISONERS DURING THE SOUTH AFRICAN WAR



A GROUP OF SERVANTS' COTTAGES OF THE PORTABLE TYPE, ERECTED BY THE SPRINGFIELD MOULDING WORKS, SPRINGFIELD, MASS., U. S. A.

83842

plain that their houses are made from a good grade of white pine, primed with one coat of paint outside. The side walls are made in sections 3 feet 2 inches wide from $\frac{3}{4}$-inch siding, tongued and grooved, each being a duplicate of the other, and all being interchangeable. For shipment these sections are put up in crates or packages of a convenient size for handling and transportation. The solid sections are interchangeable with those containing windows and doors, so that a purchaser erecting a house can arrange the windows and doors to suit his requirements. The height of the sections is 6 feet 6 inches or 7 feet 6 inches.

Where a house is desired for occupancy the year around, or in a country subject to extremes of temperature either hot or cold, a double roof and double wall house meets every requirement. The double roof is constructed with outside and inside panels, each made of $\frac{3}{4}$-inch matched white pine, and separated by a $\frac{7}{8}$-inch air space. The upper or weather surface of the outside panels is covered with heavy canvas made especially for this purpose and thoroughly painted. In the case of the double walls the outside or weather panels are made of $\frac{3}{4}$-inch white pine siding, tongued and grooved; the inside panels are made of $\frac{1}{2}$-inch white pine siding, tongued and grooved, breaking joints with the outside panels, so that the inside and outside joints do not come opposite each other. Between the outside and inside panels there is a $\frac{7}{8}$-inch air space, which is lined with moisture-proof building paper.

With these portable houses, some of the builders supply also portable furniture, meaning by this, beds, chairs, and tables, for example, of the folding kind, which, without being disconnected, can be stowed in little space for ready transportation.

PLANING MACHINE DRIVES

WITH SPECIAL REFERENCE TO AMERICAN PRACTICE IN MOTOR CONNECTION

By C. H. Benjamin

ELECTRIC driving and electric speed control for machines having a continuous motion in one direction, such as engine lathes and boring mills, have presented some rather difficult problems. These problems have been solved, at least tentatively, and it is no uncommon sight to see such machines driven by variable-speed motors and having a much larger range of speeds than formerly.

The planing machine, on account of its reciprocating motion, is not so well adapted for this kind of driving, and serious difficulties have been encountered in bringing it into line with other machines in an electrically driven shop. The inertia of the heavy platen, and of the work which it carries, requires at each reversal a large excess of power, especially at the end of the return stroke. Furthermore, the higher speed of the return causes an uneven distribution of the work when a light cut is being taken.

The need of a fly-wheel in such cases is apparent. When several small planers are to be driven, this has sometimes been accomplished by using one long overhead counter-shaft driven by a constant-speed motor and getting the fly-wheel effect by heavy pulleys on this shaft. As no two of the planers would ordinarily reverse

at the same instant, a smaller motor and smoother running were the natural results.

The increasing use of high-speed steel for cutting tools has introduced another element into the problem by making it desirable to use several cutting speeds, according to the character of the metal cut and the metal cutting. Furthermore, it is not desirable to vary the speed of return, since the cutting conditions do not affect this. Most manufacturers agree on a return speed of from 70 to 80 feet per minute.

While it has not been found practicable with the high-speed steels to attain such cutting speeds as on engine lathes, a speed of 40 or 50 feet a minute has been used satisfactorily on planing machines. Conservative builders, however, recommend a range from 15 to 35 feet a minute as sufficient for all practical purposes, with a constant return speed of 75 feet a minute. It is evident from what has been said that the desirable results to be attained in a planer-drive are (1) a constant return speed; (2) a cutting speed easily variable between the limits just mentioned; and (3) a reserve of power, or "fly-wheel effect," to take

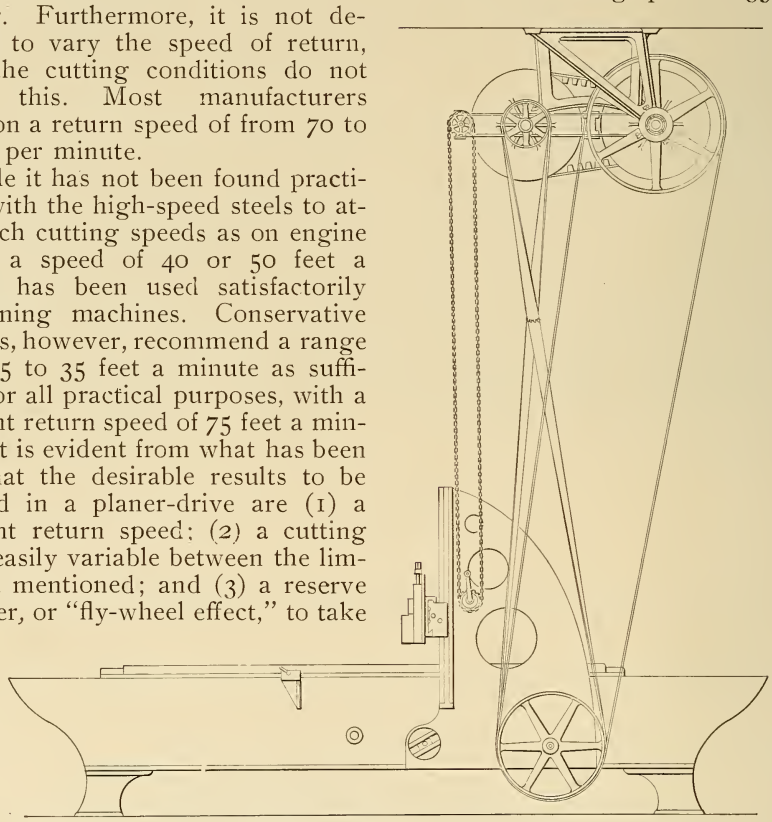


FIG. 1.—THE REEVES VARIABLE-SPEED COUNTER-SHAFT APPLIED TO A PLANER

care of the jumps at reversal. It remains to be seen how nearly these conditions have been met.

Some form of variable-speed control may be interposed between the motive power and the counter-shaft of the machine, and this method applies to mechanical as well as to electrical drives. Such is the Reeves variable-speed counter-shaft* as illustrated in Fig. 1. This device is probably too well known to need any description here. Although it works admirably under uniform conditions, it has its limitations, and these should be understood. In the first place, this method varies the return speed in the same ratio as it does the speed of cut. To attain a cutting speed of 35 feet a minute, the return should be made about two to one.

When the machine is cutting hard steel at 15 feet a minute, the return is reduced to 30 feet a minute and much time is lost. In the second place, there is some danger of the transmission device becoming jammed on account of some sudden catching of the tool occasioned by a lump on the work or by some hard spot.

Fig. 2 shows a variable-speed counter-shaft which operates on a different principle. The upper shaft is driven

* Made by the Reeves Pulley Company, Columbus, Ind., U. S. A. A description of this device was printed in this magazine for September, 1904, in an article entitled "Variable-Speed Appliances," by E. K. Hood.

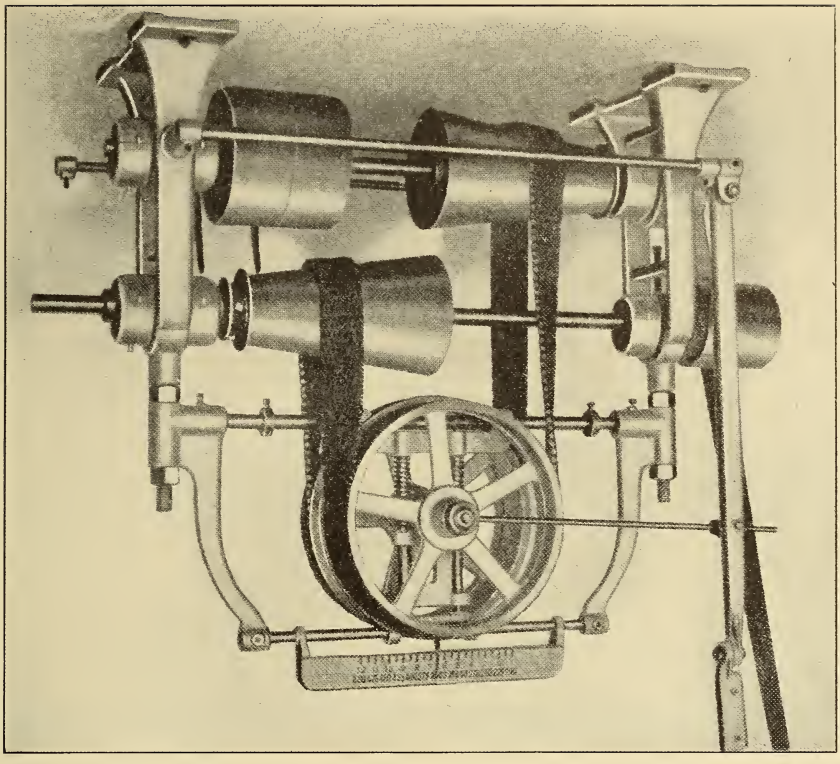


FIG. 2.—A VARIABLE-SPEED COUNTER-SHAFT MADE BY THE POWER & SPEED REGULATOR COMPANY, KALAMAZOO, MICH., U. S. A.

from the line shaft in the ordinary way, and in turn communicates motion to the lower shaft by means of belt cones and an adjustable idler. The lower shaft is belted to the machine to be driven. Moving the idler to and fro horizontally by means of a shipper rod shifts the belt on the two cones and changes the speed of the lower shaft.

In order to equalise the tension on the two sides of the belt, the guide pulleys are coned. The frame carrying the guide pulleys has a vertical adjustment controlled by spiral springs which regulate the belt tension. The pointer and scale below the wheels show the speed at which the machine is running.

The ordinary electric drives do not solve the problem of variable speed, but merely substitute electrical for mechanical transmission. Some of these should be noticed, however, as they are steps towards a solution. The following figures illustrate some of the different methods of making the connection between the planing machine and its motor, as applied by the G. A. Gray Co., of Cincinnati, U. S. A.

Fig. 3 shows the "motor-belted drive," in which the counter-shaft of the machine is mounted upon brackets cast to the housings and is driven by belt from a motor on the floor. The motor in this case is of the ordinary medium or high-speed type and has the usual rheostat and starting box. This is probably the cheapest and simplest way of driving a planer electrically, but offers no particular advantages over mechanical transmission.

Fig. 4 shows a self-contained motor drive with the substitution of a silent chain for the belt. This arrangement

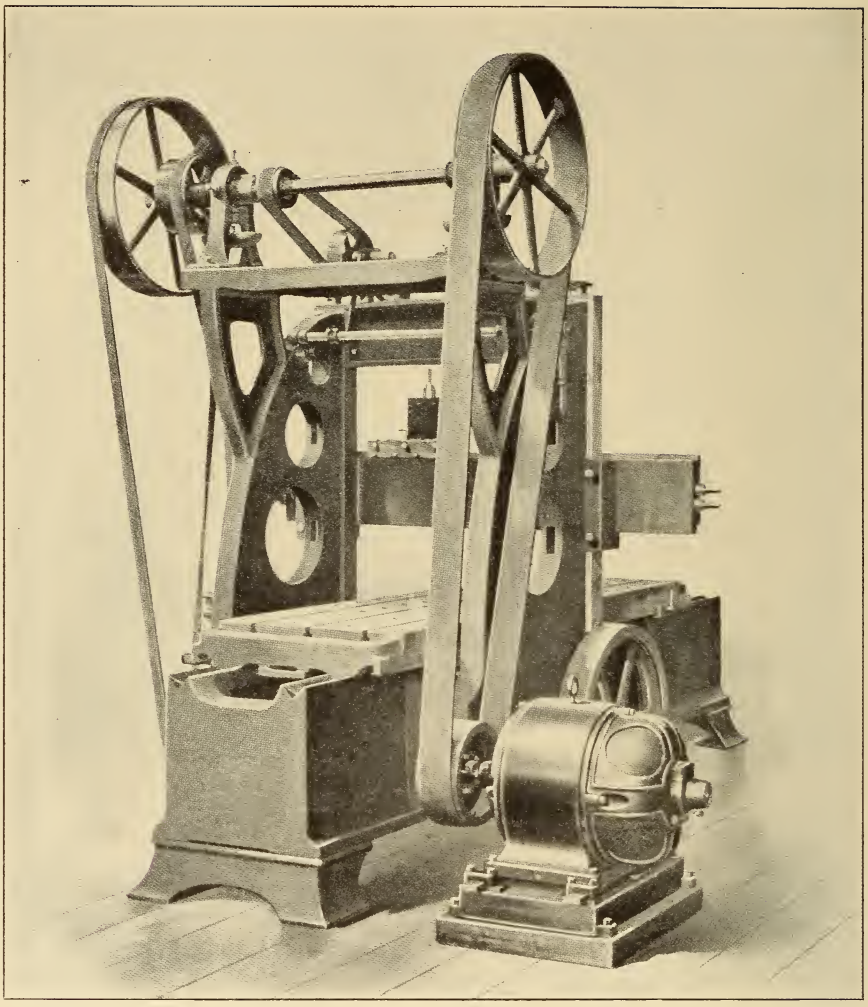


FIG. 3.—AN ELECTRIC MOTOR-BELTED DRIVE BY THE G. A. GRAY CO., CINCINNATI, OHIO

is more economical of room than that just described, but in other respects it is practically the same. The motor is a constant-speed machine, and the usual return-ratio of three to one is maintained by the counter-shaft.

Fig. 5 shows the motor direct-connected to the counter-shaft by a coupling,—an arrangement more compact than either of those just mentioned. Such a drive would usually be somewhat more expensive, from the fact that a slow-speed motor must be used.

The several devices just mentioned have the common advantage of using electricity as motive power, with whatever that may imply of convenience in starting, absence of overhead belts, and independence of line shafting; but they do not in any way solve the problem of speed control.

Fig. 6, on the other hand, illustrates an electric-driving mechanism applied to a planer, which is capable of giving different speeds to the table during the cutting stroke. This mechanism was designed by the Crocker-Wheeler Company, of Ampere, N. J., for a planer to be used in their own shop. A Crocker-Wheeler variable-speed

motor is used, the speeds in this instance running from 100 to 700 revolutions per minute, and the horsepower being 35.

As may be seen from the illustration, the motor is direct-connected to the counter-shaft and this, in turn, to the driving mechanism by a series of clutches and gears somewhat similar to those used in the transmission gears of automobiles. By turning a hand-wheel provided with a dial, the speed of the table can be changed at will. Four different speeds can be obtained in this manner, those for the highest speed of motor (700 revolutions a minute) being 15, 20, 26 and 35 feet a minute.

The speed of return remains the same,—70 feet a minute. It is evident from the figures given that the variable speed of the motor was not intended to be much of a factor in the results, since with the motor at its highest speed the cutting speeds are normal. The only effect of reducing the speed of the motor would be to reduce the speed of cutting and return below the normal and reduce the power of the machine.

One very interesting phase in the development of electric driving for planers was the use of magnetic clutches as brought about by the Electric Controller & Supply Company, of Cleveland, U. S. A. Two clutches at the side of the planer were driven in opposite directions by an electric motor acting through gearing and, being alternately magnetised and demagnetised by the movement of the platen, operated, in turn, on the driving gears. However well this mechanism may have worked, it was rather complicated and expensive and had to give way to a later invention of the same company, the reversing, variable-speed motor.

At the present time no argument is necessary to show the desirability of a simple and easily operated speed control in order to secure at all times

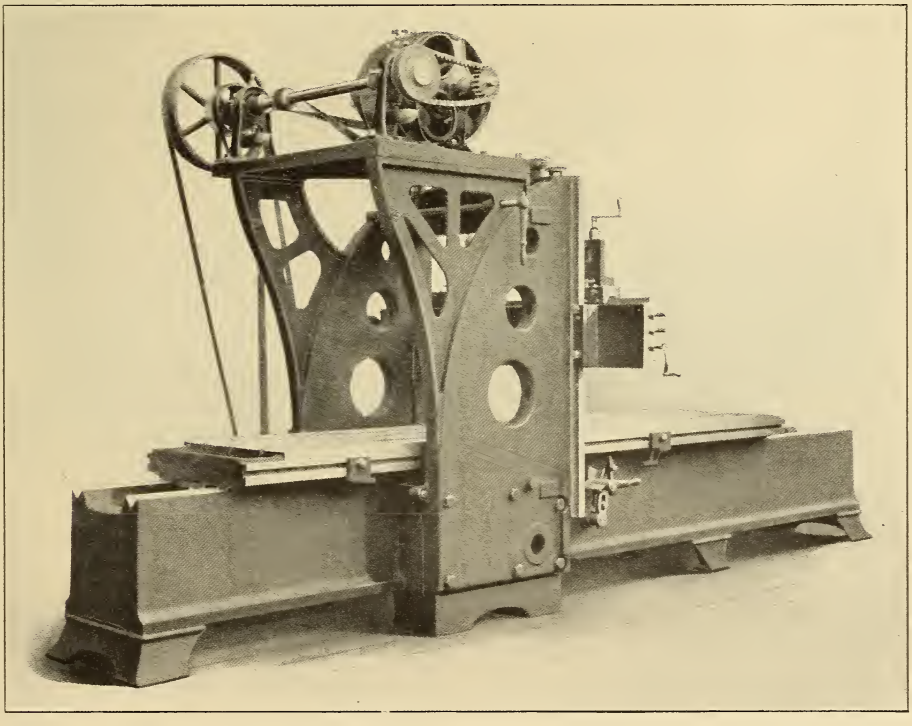


FIG. 4.—A SELF-CONTAINED ELECTRIC MOTOR DRIVE USING A "SILENT" CHAIN IN PLACE OF A BELT

the greatest efficiency of machine. No other question is economically so important to the manufacturer as that of securing the greatest output per machine and per man.

In the past no machine has come further from economical performance than the ordinary planer when used on widely varying classes of work. It was so designed that it must cut cast-iron, soft steel and hard steel at the same speed, and that it must run the heavy roughing tool at the same speed as the more delicate tools used in finishing. Some of the means employed for overcoming this difficulty have already been noticed.

In the planer-drive about to be described, a variable-speed motor acts directly on the cross-shaft of the machine, without the intervention of belts or clutches, and is itself reversed at the end of each stroke by means of a reversing switch and the dogs on the platen. In order that this may be done successfully, an automatic controller is provided, which gradually accelerates the motion of the platen after reversal and limits the amount of current going to the motor, so that there is no sparking or danger of injuring the motor.

During the cutting stroke the platen is thus accelerated to a speed determined by a so-called operating controller. During the return stroke the maximum speed attained would always be the same. A dial attached to the operating controller shows the cutting speed in feet per minute. The operation of reversing the machine by hand is just the same as on an ordi-

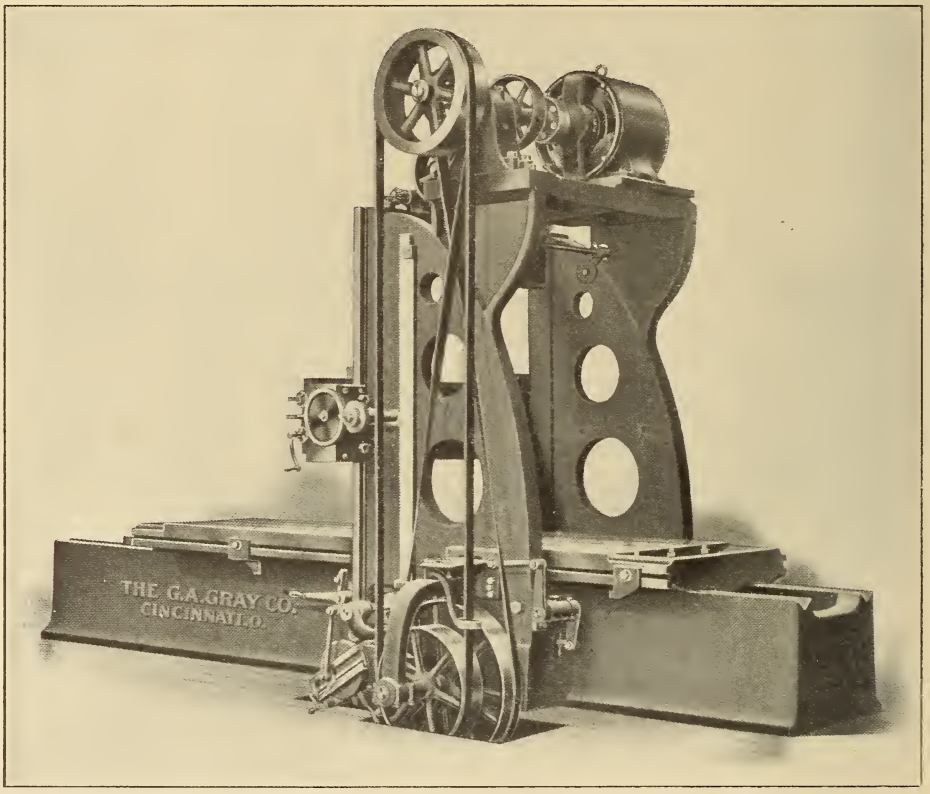


FIG. 5.—A DIRECT-CONNECTED ELECTRIC MOTOR DRIVE BY THE G. A. GRAY CO.

nary planer and can be performed by any workman who is familiar with planer work.

Fig. 8 shows this form of drive applied to a 36 by 36-inch by 12-foot

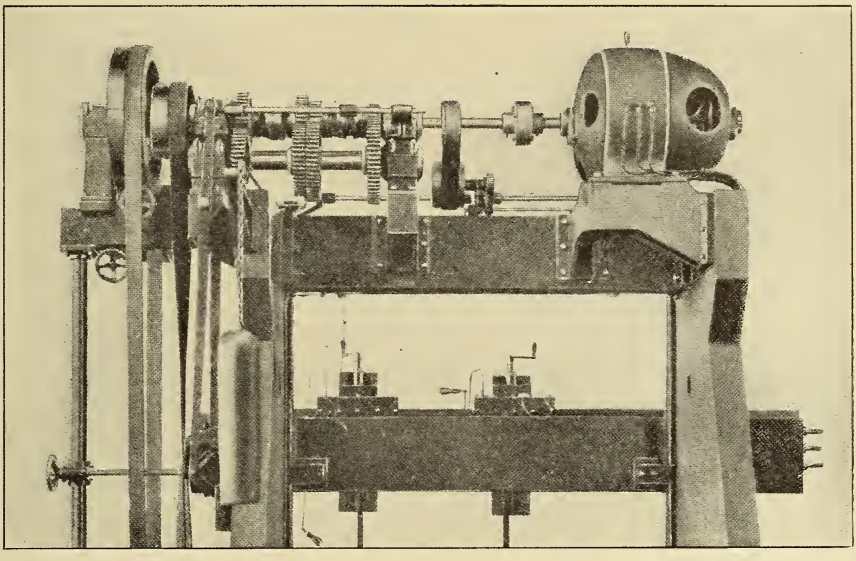


FIG. 6.—AN ELECTRIC DRIVING MECHANISM CAPABLE OF GIVING DIFFERENT SPEEDS TO A PLANER TABLE DURING THE CUTTING STROKE. DESIGNED BY THE CROCKER-WHEELER CO., AMPERE, N. J., U. S. A.

planer. The motor is of the direct-current, compound-wound, variable-speed type made by the Westinghouse Company, the speed limits being 250 and 1000 revolutions a minute.

The reversing switch box may be seen in the foreground at the left. The dogs on the table are shown as set for a short cut, and the hand reversing lever may be clearly seen. This lever may be manipulated just as in the ordinary machine to start, stop, or reverse the platen, and is connected with a similar lever on the opposite side of the machine so that the platen may be handled from either side. Above the motor, at the left, are the two operating controllers, one for the cutting and one for the return stroke. Eleven contacts are shown, which means eleven speeds. In case it is desired to cut on both strokes, the speed can be varied on the return stroke as well.

Fig. 7 shows the reversing switch and the speed controllers with the cases removed. At the right of both figures is shown the accelerating controller which is really the key of the whole design. There is a series of three magnetic switches which control the current to the motor. When the reversing switch is thrown, the first accelerating switch closes. This allows the second switch to close when the current has dropped to a certain point. Another increase of current follows, with a gradual falling off until the third switch closes. The current thus has three maximum points, none of which can exceed a limit determined in advance. A retarding switch is also provided which operates near the end of each stroke by connecting up the motor as a generator, thus absorbing the energy of the moving parts and bringing the platen gradually to rest.

Another special switch is ordinarily held open by a solenoid, but if the

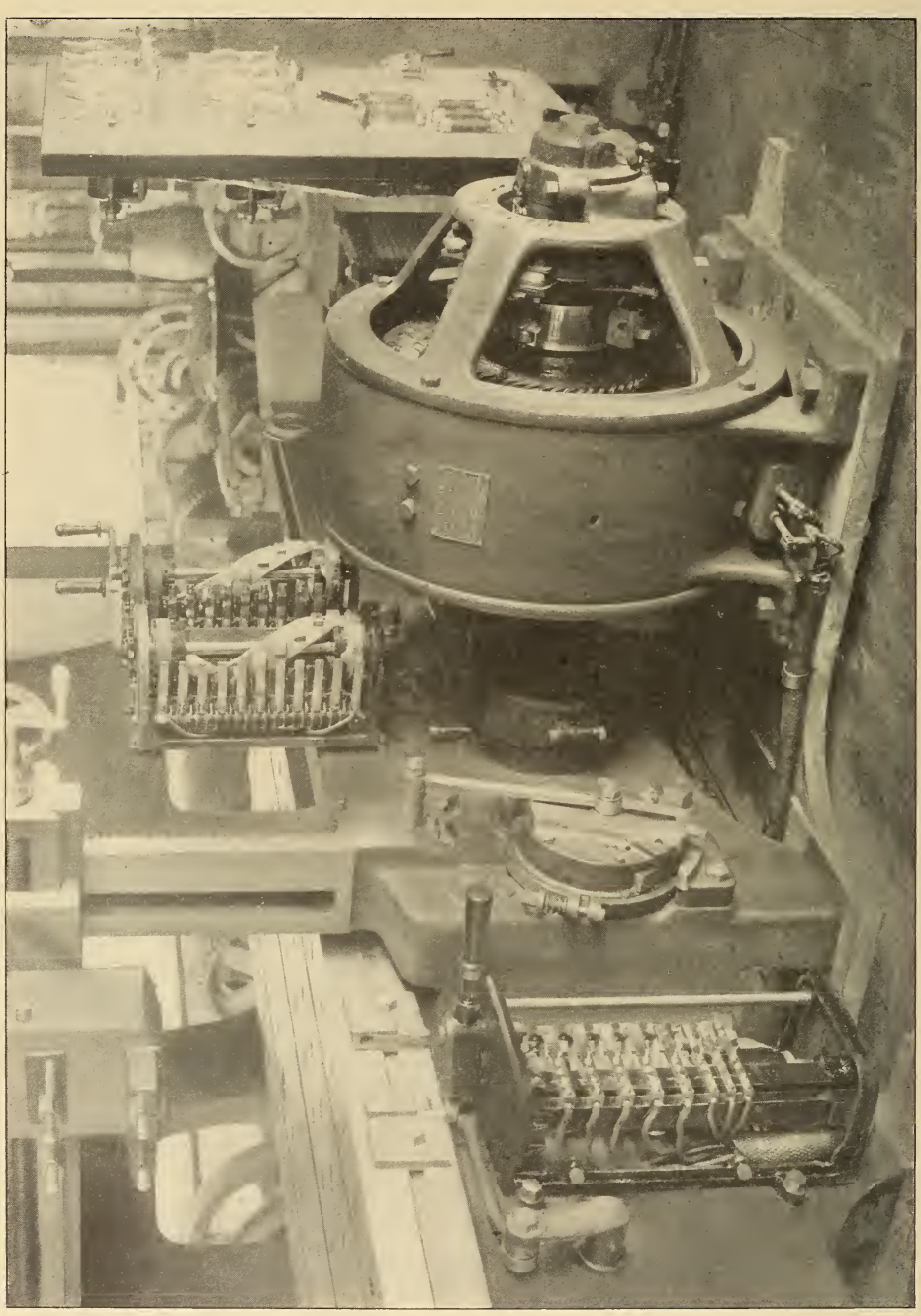


FIG. 7.—REVERSING SWITCH AND SPEED CONTROLLERS

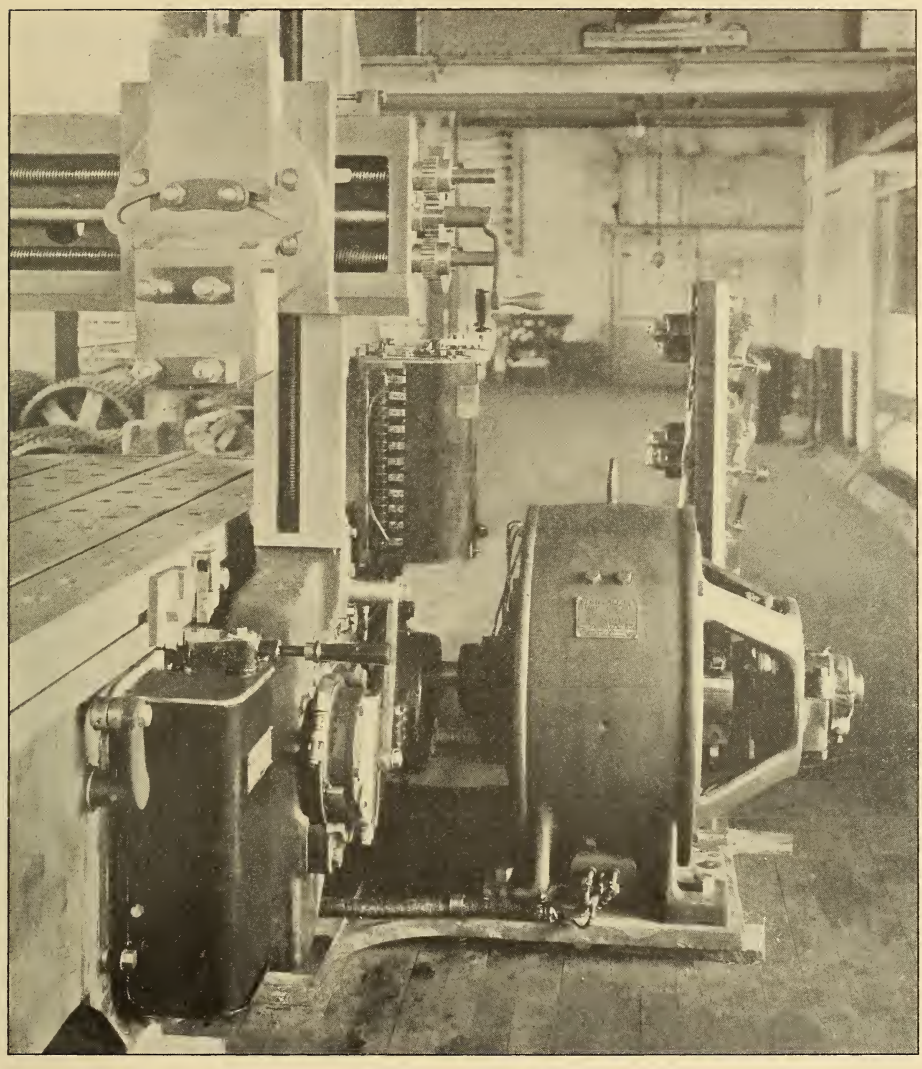


FIG. 8.—A WESTINGHOUSE REVERSING MOTOR APPLIED TO A PLANER

current fails for any reason, the switch closes at once, changes the motor into a generator, and instantly stops the machine. A double-throw switch and starting box on this same board operate a small motor mounted on the top brace of the machine and used for raising and lowering the cross rail.

The motor is guaranteed to maintain its rated horse-power throughout the entire range of speeds. For the ordinary single-voltage system this range is two and one-half to one, but with the 110 and 220-volt, three-wire system used on the planer shown, the range is five to one.

What would seem to recommend this system to the ordinary engineer would be the absence of belts and clutches, the similarity of the hand control to that generally used, and the simplicity of the speed control. In other words, here is a machine which can be run by any good planer hand and easily adjusted to give the cutting and return speeds which are most eco-

nomical for the work in hand. The writer has seen a large planing machine driven in this way, running on regular work, and was impressed with two facts,—the almost entire absence of sparking at the commutator and the precision of the reversal as determined by inspecion of the limits of travel of the platen.

It is not to be supposed that the last word has yet been said regarding planer-drives, as all experience would point to the contrary; but it is evident that an important step has been taken in the direction of a satisfactory solution.

The appended table shows the results of some experiments made by the Electric Controller & Supply Company on a planer equipped in this manner and exhibited at the St. Louis Exposition. The table is self-explanatory and needs no further word:—

TEST OF 36″ x 36″ POND PLANER

Driven by the Electric Controller & Supply Company's Improved Motor Drive

	Amperes Cut	Volts Cut	Speed Cut	Amp. Return	Volts Return	Speed Return
No. load..	12	115	16	12	233	35
No. load..	22	115	37	20	230	75
No. load..	14	222	32	20	225	75
No. load..	20	222	77	20	222	78

During acceleration cutting stroke and armature on 110 volts: Speed of platen, from 16 to 37 feet; amperes input, 35 to 45; throw of needle at instant of starting, about 60 amperes.

During acceleration return stroke or cutting stroke and armature on 220 volts: Speed of platen, from 30 to 80 feet; amperes input, 40 to 60; throw of needle at instant of starting, about 80 amperes. Motor is rated at 48 amperes, 110 or 220 volts.

CUTTING CAST IRON

Cut Inch	Amp.	Volts	Speed	Kw.	H.P.	H.P. per Lb. Cast Iron per Min.
1½ x 1/32	58	115	32	6.67	8.93	1.90
1½ x 1/32	32	222	32	7.10	9.50	2.03
1½ x 1/32	60	220	73	13.20	17.69	1.65
1½ x 1/16	40	220	32	8.80	11.79	1.26
1½ x 1/16	78	218	68	17.00	22.78	1.14
1½ x 1/16	42	117	13	4.91	6.58	1.72
1½ x 1/16	78	115	25	8.97	12.02	1.64
1½ x 3/32	60	112	12½	6.72	9.00	1.65
1½ x 3/32	120	110	23	13.20	17.69	1.74
1½ x 3/32	52	225	31	11.70	15.68	1.15
1½ x 3/32	115	226	67	25.99	34.83	1.18

CUTTING STEEL

Cut Inch	Amp.	Volts	Speed	Kw.	H.P.	H.P. per Lb. Steel per Min.
½ x 3/32	110	220	67	24.20	32.43	3.01
½ x 3/32	52	222	30	11.54	15.46	3.21
½ x 3/32	58	112	11	6.49	8.70	4.93
½ x 3/32	136	110	20	14.96	20.05	6.26
½ x 1/16	45	112	12	5.04	6.75	5.25
½ x 1/16	72	112	26	8.06	10.80	3.88
½ x 1/16	52	220	35	11.44	15.33	4.08
½ x 1/16	100	218	66	21.80	29.22	4.13
½ x 1/32	30	220	37	6.60	8.84	4.47
½ x 1/32	58	220	75	12.76	17.10	4.27
½ x 1/32	30	110	13	3.30	4.42	6.37
½ x 1/32	50	110	30	5.50	7.37	4.60

No. 7, type "S" Westinghouse Manufacturing Company motor.

No sparking whatever except when armature was taking 115 amperes, 226 volts, and 120 and 136 amperes, 110 volts, when sparking was so slight as not to be objectionable. Weight of cast iron taken as .26 pound per cubic inch; steel as .285 pound per cubic inch.

THE WATER SUPPLY OF COUNTRY BUILDINGS

By Wm. Paul Gerhard, C. E., M. Am. Soc. M. E.

PART III.—CONSIDERATIONS OF STORAGE AND DISTRIBUTION

Concluded from the May Number

HAVING provided the pumping apparatus, it becomes necessary to decide upon the means for storage, and incidentally to determine the required storage capacity. In the case of large country mansions and institutions, an ample storage of water is essential. Where a site can be found at an elevation suitable to deliver water to the building and the grounds under sufficient pressure, a reservoir may be built. This may be constructed either of earth or of stone masonry; it is built economically by putting it partly in excavation and partly above ground.

Reservoirs may be built either open or covered; it is best to design them in two, about equal, sections to permit of cleaning the one while the other remains in service. They should contain at least a ten days' supply of water. In the case of ground waters, and also for all water which has been filtered, covered or arched-over reservoirs, as in Fig. 31, are required to exclude, in the one case the sunlight, in the other dust and atmospheric impurities. It has been mentioned heretofore that sunlight promotes vegetable growth in the case of ground waters, imparting to them a bad taste and odour.

In those country districts where stones abound, a service reservoir may sometimes be built at small expense, but as a rule its construction, if built in brickwork or concrete, and if made water-tight with asphalt or cement, involves a higher cost than owners of country houses are willing to incur; hence, reservoirs can be planned only in the case of larger buildings or groups of them.

For the majority of individual buildings water is stored in elevated tanks.

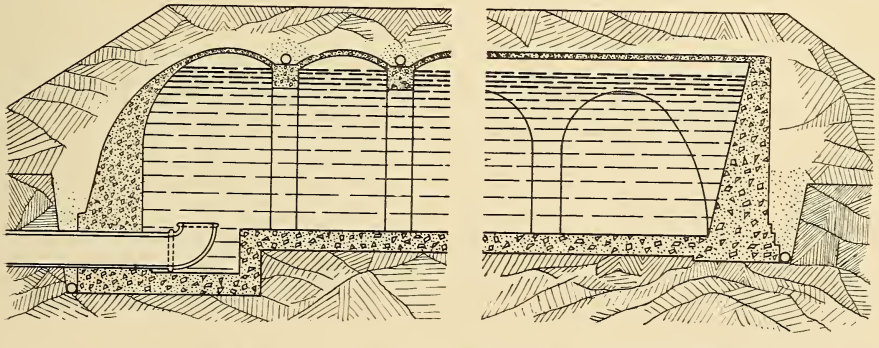


FIG. 31.—CROSS AND LONGITUDINAL SECTIONS OF A COVERED RESERVOIR

FIG. 32.—SECTIONAL, ALL-IRON TOWER. MADE BY THE W. E. CALDWELL CO, LOUISVILLE, KENTUCKY, U. S. A.

These may be constructed of either wood, steel, or iron, and the supporting structure is built either in wood, in steel, or of masonry. Combinations of these materials occur, such as a wooden tank on a steel tower, as in Figs. 32 and 33, or a wooden or iron tank on a masonry tower. Wooden or iron towers, if left open, do not enhance the beauty of the landscape. In many cases, therefore, the towers are enclosed or ornamented, and quite often such a water tower can be utilised as an obseratory where an attractive view of the surrounding country exists.

Tank towers should be proportioned and constructed so as to be amply strong to carry the heavy load of a tank filled with water, and they should have good foundations carried below the frost line. The specifications for these should require the best obtainable material and workmanship, because exposed towers must suffer the deteriorating effects of the weather, and they also must be able to withstand heavy wind pressures.

In exceptional cases, as in Fig. 34, two, and sometimes even three, tanks are placed on the same tower, one under the other,—the highest being in-

tended for fire service, the middle one for the house supply, and the lowest for the supply to the grounds, and to the generally low barn and stable buildings. The tanks are, in such cases, piped so as to be interconnected.

Wooden tanks are always built circular, because this shape is found to be best to secure tightness. All sizes from 3 feet to 32 feet in diameter, and with staves from 3 to 24 feet in length, are manufactured, the capacities ranging from 150 to 120,000 U. S. gallons. The special lumber used for tanks is either cedar, cypress, white pine, or Oregon fir.

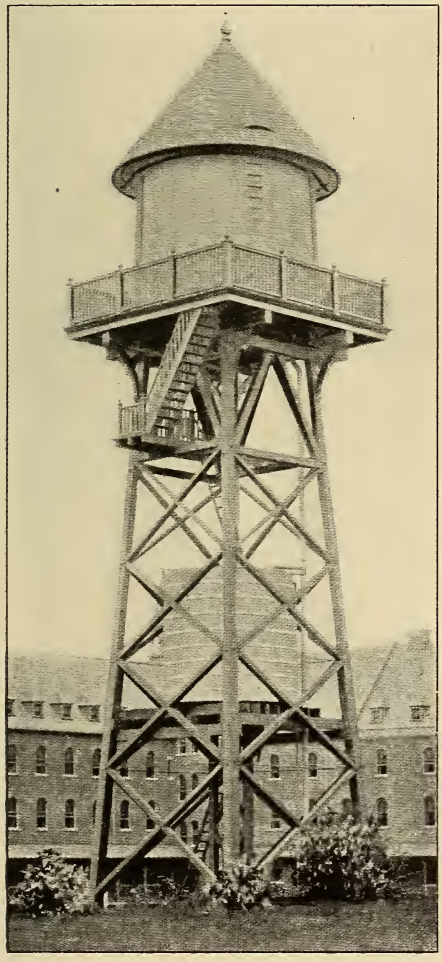


FIG. 34—A SINGLE TOWER SUPPORTING TWO TANKS, ERECTED BY A. J. CORCORAN, JERSEY CITY, N. J.

FIG. 33.—ANOTHER SECTIONAL ALL-IRON CALDWEL COMPANY TOWER

Some tank manufacturers claim that for exposed tanks nothing is better than Red Gulf cypress, but others prefer the pine wood. Cypress wood is soft, coarse-grained, and porous, and easily becomes water-soaked. Tanks of this material leak more, and are easier affected by frost in the Northern climate, whereas pine is close-grained, and such tanks are more readily made tight and are otherwise just as durable.

Tank lumber should be clear, selected stock, thoroughly air-dried and free from knots, worm holes and shakes. The staves and the bottoms are made of 2½ or 3-inch stock; the staves, which should not be wider than 8 inches, are surfaced and sawed to

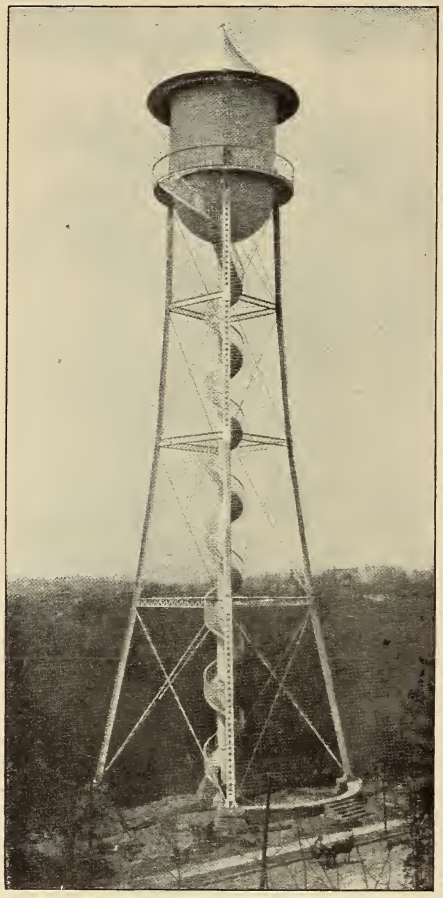


FIG. 35.—IRON TANK WITH HEMISPHERICAL BOTTOM MADE BY THE CHICAGO BRIDGE & IRON COMPANY, CHICAGO

the proper bevel. They are doweled together by means of dowel pins placed about 4 feet apart. All staves must be of full length and not spliced.

The strength of wooden tanks depends upon the iron or steel hoops with which they are encircled, and which always have lugs and bolts to tighten the tank. Hoops are either flat or round; the latter, which are required by the underwriters, are preferable, because they can be better examined and protected from rust. The diameter, number and spacing of the hoops depend upon the size and capacity of the tank. All hoops should be well painted before being put on, and should be given another coat after the tank is erected. It is essential, in the construction of a wooden tank, that the weight of water should be supported entirely from its bottom, and therefore sleepers are laid under the tank bottom and cut to the circumference of the tank but a few inches shorter. Wooden tanks when left standing empty and exposed to the sun become leaky; those intended for winter service should always be frostproofed in the best manner.

Wooden tanks of an oblong or square shape cannot be made to stay tight without being lined with sheet metal the same as the inside house tanks; for this reason they are but rarely used.

Iron tanks are made either square or round, and are built of cast iron, or else of wrought iron and steel. Square cast-iron tanks, consisting of numerous sections bolted together with tightly made joints, are used only in the interior of buildings. Outside tanks are made of wrought iron or of steel with riveted joints, and such tanks are nearly always round in section. They cost from 50 to 100 per cent. more than wooden tanks without having superior advantages to offset the larger cost.

Iron tanks are commonly made with a flat bottom, but this requires the placing of a number of iron beams at short intervals under the bottom. A considerable saving can be effected in the cost of the supports by making the bottoms of tanks either hemispherical as in Fig. 35, or conical, or else by using a compound shape and supporting the tank directly and only at its

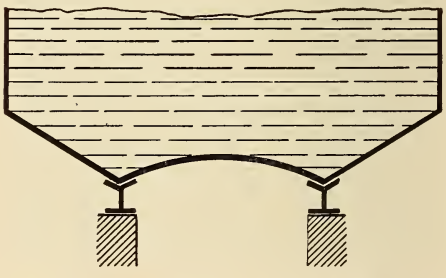


FIG. 36.—A MODERN FORM OF TANK BOTTOM AND SUPPORT

circumference, as in Figs. 36 and 37. An incidental advantage of these more modern forms of tanks is that the bottom can be better inspected and repainted.

The reasons why wooden tanks are more often used than steel tanks are that the latter are more difficult to erect, that they give trouble by reason of sweating, and that they rust soon if the outside paint is not constantly renewed. Iron tanks are also more difficult to protect against freezing. Where very large storage capacities exceeding 100,000 gallons are necessary, iron tanks must be used. Hence we find iron tanks such as those shown in Figs. 38, 39 and 40 used largely in the water supply of small towns. But such sizes are rarely called for for country mansions, and therefore wooden tanks are preferred. In practice it is found that the latter last from 15 to 25 years, are not so liable to freeze, do not rust, keep the water pure and clear, and can be bought and put up for much less money.

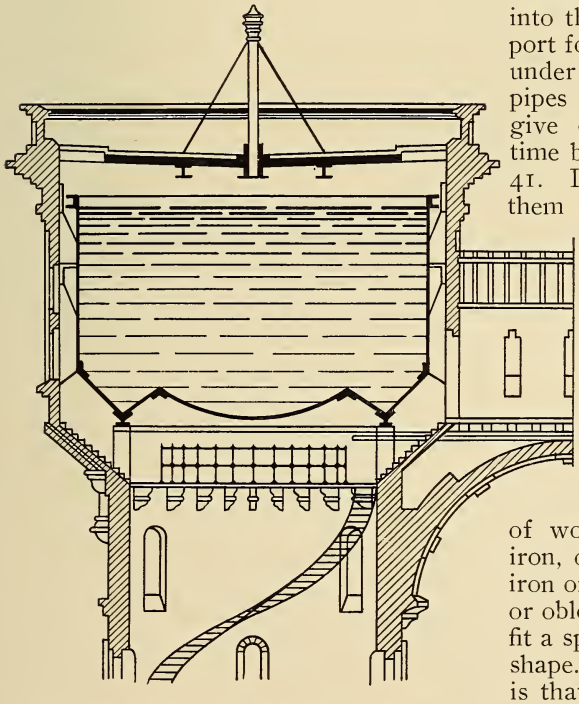


FIG. 38.—A TYPE OF IRON TANK USED LARGELY IN THE WATER SUPPLY OF SMALL TOWNS

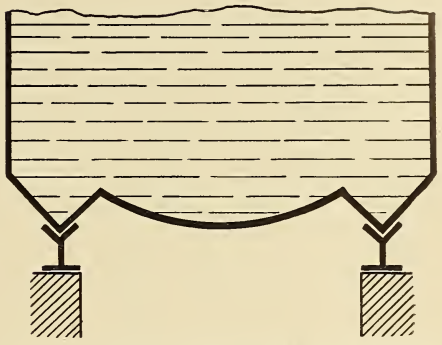


FIG. 37.—ANOTHER COMPOUND FORM OF TANK BOTTOM AND SUPPORT

Instead of providing elevated storage tanks, the water is sometimes pumped into standpipes. They are built either of boiler iron or steel, and are always small in diameter as compared to their height. (See Fig. 43.) Such standpipes are erected directly on the ground or on suitable stone foundations, and the water pumped into the lower portion forms the support for the water that is stored for use under the available pressure. Standpipes are often left unenclosed, and give considerable trouble in winter time by ice forming, as shown in Fig. 41. It is safer and better to enclose them with masonry as a protection against freezing, but this adds greatly to their cost, and hence standpipes are not used to any extent in the case of country buildings.

Water for a dwelling may be stored in inside tanks located in the attic, or in the case of institutions sometimes located in the main staircase tower. Such tanks are built of wood lined with copper, of cast iron, of slate, and finally of wrought iron or steel. They are usually square or oblong in shape, but can be made to fit a space of irregular dimensions and shape. The objection to inside tanks is that their size must necessarily be limited, hence they provide an insufficient storage of water. Where an

outside tank can be provided it is much better to do so.

Another method of storing water consists in providing pressure tanks. These are closed, riveted boiler iron or steel tanks, of any required dimensions, conveniently placed either on or, more often, below the level of the ground. Owing to this location they do not require any expensive supports such as the elevated tanks have, but their weight necessarily requires good foundations. As a rule, such pressure tanks are designed to be kept two-thirds full of water, the remaining one-third being filled with air under pressure.

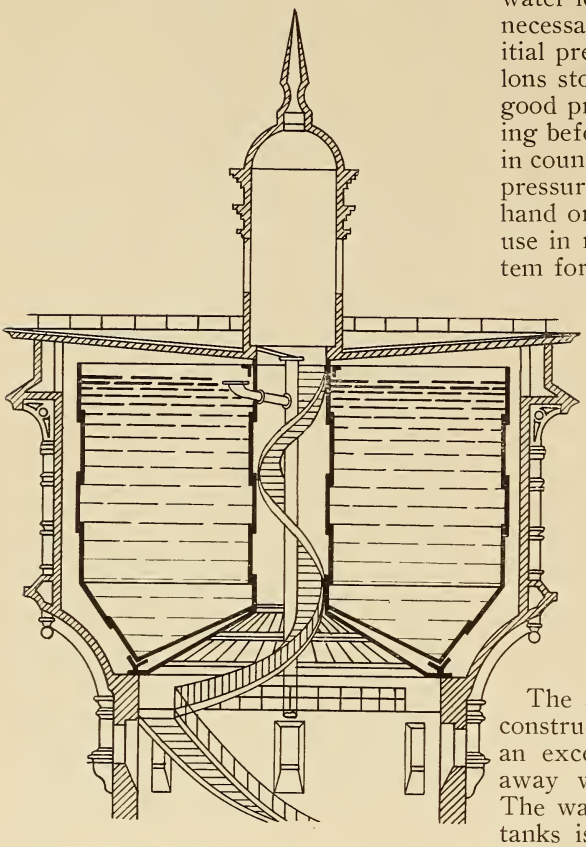


FIG. 39.—A TYPE OF IRON TANK USED LARGELY FOR THE WATER SUPPLY OF SMALL TOWNS

Pressure tanks are always cylindrical in shape, and may be placed either horizontally or vertically. When used without an air compressor, pressure tanks have the disadvantage that the flow of water becomes reduced as the water level is lowered. It is therefore necessary either to provide a high initial pressure, so that the last few gallons stored may be delivered under a good pressure, or else to renew pumping before the tank is empty. For use in country houses several systems with pressure tanks, operated either with hand or power pumps, have come into use in recent years, and a simple system for use in a small country house, with hand pump, is shown in Fig. 42.

A good modification of the pressure tank system was invented and patented years ago by the well-known engineer W. E. Worthen, and many examples of this system in its improved form, known as the Acme water storage system, have been constructed, not alone for country towns, but also for isolated country dwellings. The system has many sanitary and constructive advantages, provides for an excellent fire protection and does away with the use of fire engines. The water stored in the underground tanks is kept cool, remains pure and cannot become contaminated as in the open tanks. Moreover, in the case of underground sources of supply, there is no exposure of the water to the sun's rays, hence there will be no annoying growth of algæ. There is also no trouble from freezing of the water in the reservoir.

The chief advantage gained is that the last gallon of water in the tank is supplied under a good pressure, which cannot be accomplished with pressure-tank systems without air tanks. For the supply of buildings composing a military post, the system has the advantage from a strategic point of view, that there is no standpipe or elevated tank at which the guns of an enemy could be aimed, hence the water supply cannot be cut

off or destroyed. In all cases where objection is raised to the appearance of an elevated tank, or to the heavy additional expense required to make it look well, this system is well adapted and worth investigating. It is illustrated in Figs. 44 and 45.

Having pumped the water and stored it in elevated tanks or reservoirs, we must bring it to the places of consumption by a main conduit pipe. In the cases of important buildings it is advisable to install this main pipe in duplicate, so as to provide against the cutting off of the supply in case of a break. Larger conduits are always built of cast iron pipes with lead calked joints, and when the pressure is heavy, considerable attention must be given to the proper jointing of the pipes to avoid constant leakage and consequent waste of water.

The main conduit pipe connects at the building with the outside distribution system. Such a system can be laid out in two ways. In one, the ramified system, the pipes are arranged like the trunk, branches and twigs of a tree, becoming smaller in diameter as the distance from the main conduit increases. The laterals and branch lines thus form dead ends, and while this may not matter in the case of a single country house with its outbuildings, the matter is of importance in the case of groups of buildings or large institutions. For such, it is far better to adopt the second or circulatory system illustrated in Figs. 46 and 47, which has no dead ends, and in which the extreme pipe ends are looped so that the water cannot stagnate. This system has the further vital advantage of maintaining a supply to the individual buildings in case a part of the distribution main is shut off for repairs.

In laying out a water supply distribution system comprising mains, submains and laterals, it is always best to provide large mains for the sake of efficient fire protection (see Figs. 46 and 47) and to carry large laterals, not less than 4, and preferably 6, inches

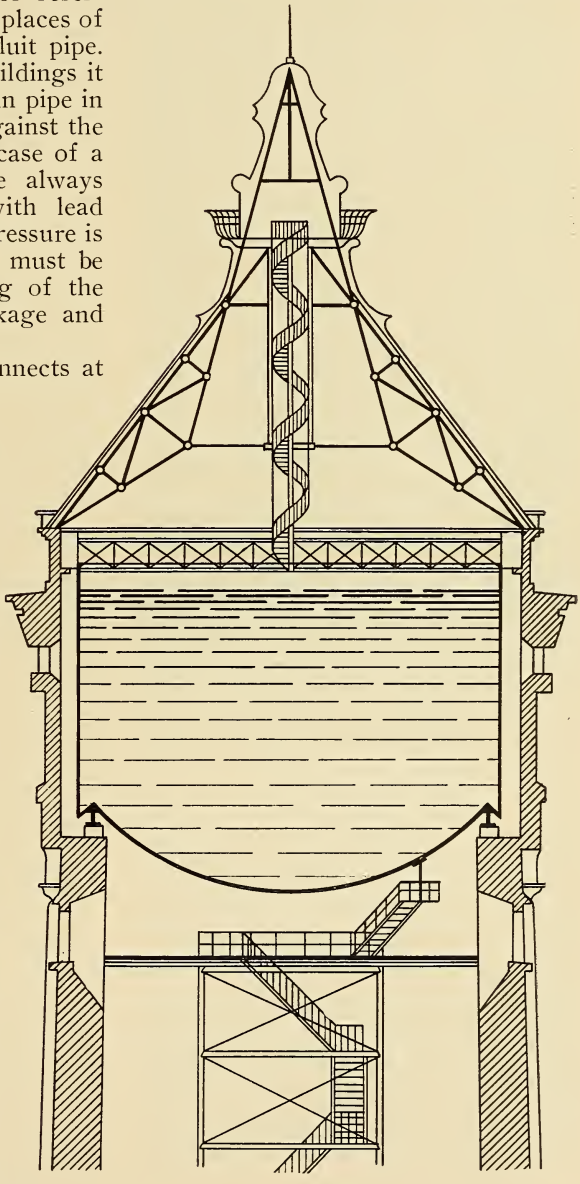


FIG. 40.—ANOTHER TYPE OF IRON TANK USED LARGELY FOR THE WATER SUPPLY OF SMALL TOWNS

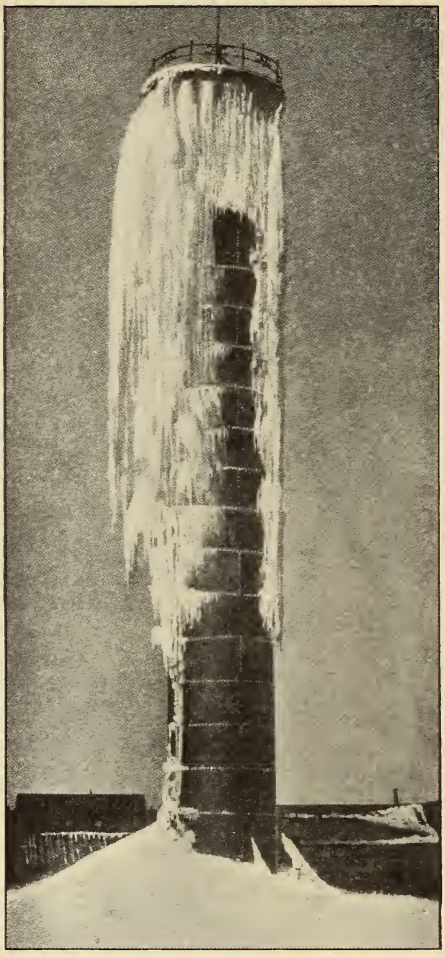


FIG. 41.—AN EXAMPLE OF WHAT MAY BE EXPECTED FROM AN UNPROTECTED STANDPIPE IN WINTER

in size, to the fire hydrants. It is good policy to provide plenty of valves, so that in case of a break in a pipe line a part of the system only is put out of commission temporarily.

The inside water service system is, even in the case of a single country mansion, more intricate than the outside water supply; in the case of a group of buildings the work of planning the inside distribution becomes at times quite complicated. There is always required a double system of water pipes, one for cold and the other for hot water. Sometimes a third system for artificially cooled water is added, and in other cases country residences require a double pipe system for rain and for well or spring water. In its essential details the inside water service does not differ from that for city houses.

The distribution system is either a so-called header system, in which separate runs are provided to each riser, all coming from a single centre or header, or else it is a circuit system in which large mains for cold and for hot water are provided, from which short branches are thrown off to all the risers. The first system requires more piping, but the pipes become of a smaller size and the control of lines and drips is placed at one central convenient point. It is more expensive in first cost, but it is handier to look after. In the second system the valves controlling the risers are scattered, therefore it is not so convenient and compact for the engineer in charge of the plant, but it has some advantages, being cheaper, not requiring so many pipe lines, and consequently not so much space at the cellar ceiling.

In arranging the water piping in the interior of buildings several essential rules must be followed, such as the placing of pipe lines where they will not freeze, or, where they are unavoidably exposed, the suitable protecting of the pipes against damage by frost. Noise and water hammer in the supply pipes must be prevented as much as possible, and the heating up of a cold water line from an adjoining hot water pipe, steam line or flue, should be guarded against.

In the hot water supply system, circulation pipes should always be provided to permit of the instant drawing of hot water at any faucet in the house; this measure prevents much useless waste of water. In running a circulation pipe it should be remembered that if it rises in loop form above the highest fixture, an air cock should be provided at the top of the loop to avoid air binding. In laying out a supply system, the aim should also be to arrange the pipes and proportion their sizes so that there will be a good,

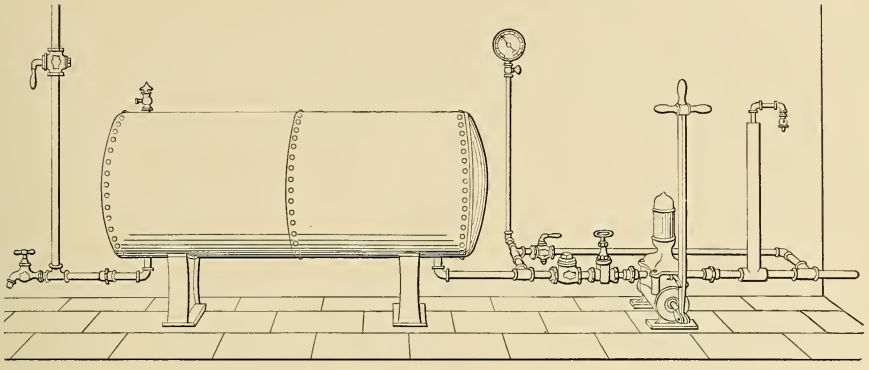


FIG42.— A SIMPLE PRESSURE TANK SYSTEM OPERATED WITH HAND PUMP. AS INSTALLED BY THE LEADER IRON WORKS, DECATUR, ILL., U. S. A.

constant and uninterrupted flow at all faucets in the building if they are kept running simultaneously.

Regarding the materials used for the water supply service, it is customary to run the lines with galvanized or asphalted wrought iron pipe with screw joints where the outside mains and laterals are not larger than 4 inches. The outside hydrants may be either post hydrants or flush hydrants, and it is well to provide a shut-off gate valve at each. In the case of institutions, all hydrants should be post hydrants with indicators. On long lines it is well to provide blow-offs at low points so that the line may be emptied; this is essential where a pipe line is put in for summer use only. At high points in a main conduit line, air valves are provided to prevent air binding, and these are sometimes arranged to work automatically.

Of special importance in the case of country residences and mansions is the matter of their fire protection. As a rule, such residences are much more in danger from fire than city houses,— they are usually located at a distance from any regular fire department; their supply of water often falls short of the demand; quite usually they are built in a flimsy manner with little or no regard to safety from fire, and, moreover, they are but seldom provided with proper means for the extinguishment of a conflagration.

It is quite exceptional to find proper attention paid to the matter of fire protection, though in some instances money is uselessly spent on worthless

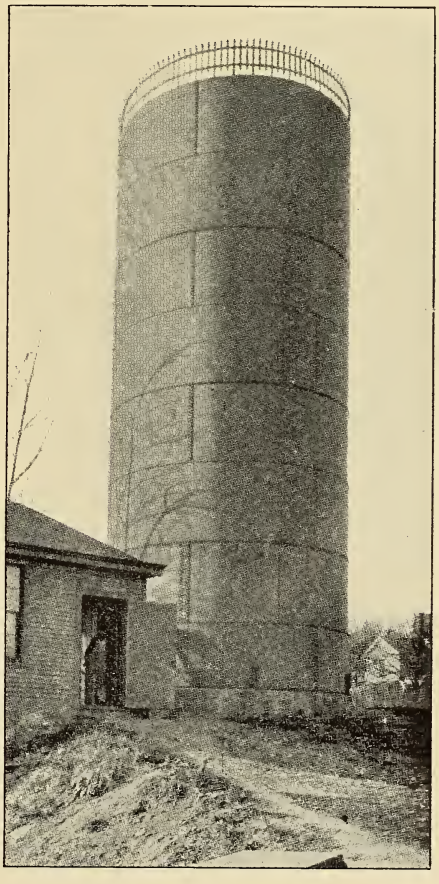


FIG 43.—A TYPICAL FORM OF STANDPIPE

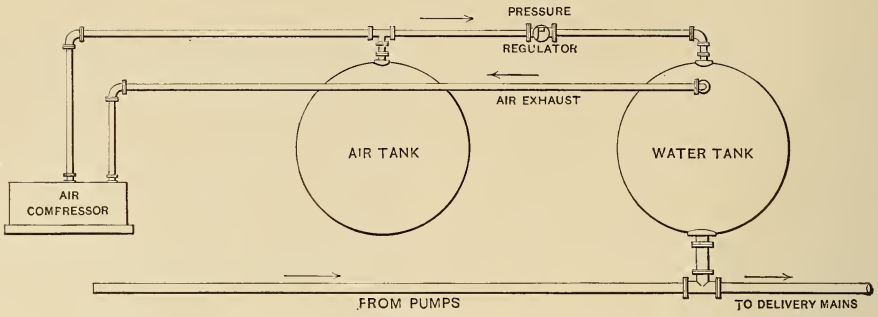
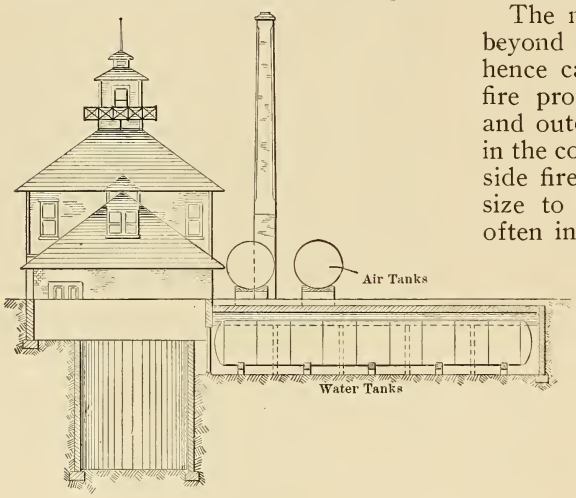


FIG. 44.—THE ACME WATER STORAGE SYSTEM. A MODIFICATION OF THE PRESSURE TANK SYSTEM. INSTALLED BY THE ACME WATER STORAGE & CONSTRUCTION CO., NEW YORK

fire apparatus, put in largely with a view of getting a reduction in the insurance rates. While it is true that a rebate in the insurance rates is given by underwriters, this only applies—and properly so—where a fire protection system is well arranged and in accordance with their requirements.

The means for fire prevention are beyond the limits of this article and hence cannot be discussed; those for fire protection comprise both indoor and outdoor appliances. Many houses in the country are provided with an inside fire standpipe much too small in size to be effective; the pressure is often insufficient, and the fire hose of a worthless type; outdoor fire appliances are lacking entirely in the case of many fine country estates.



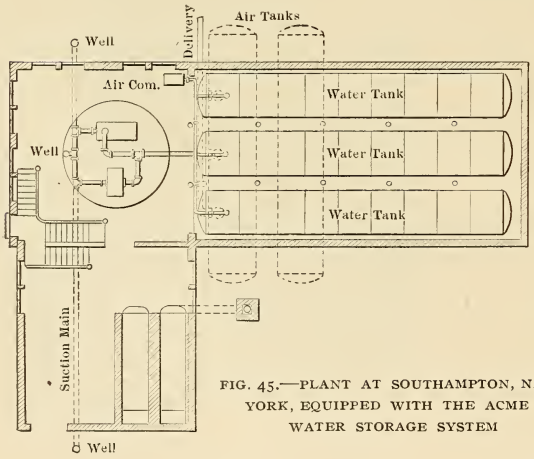


FIG. 45.—PLANT AT SOUTHAMPTON, NEW YORK, EQUIPPED WITH THE ACME WATER STORAGE SYSTEM

Every mansion and every institution located in the country should have a sufficient number of outside fire hydrants. In determining the distance between them, it should be remembered that cast-iron pipe is cheaper than hose, considering the life of both. The mains supplying the hydrants should be ample in size. For use at the hydrants there should be provided best quality large rubber-lined hose, hose spanners, hose carts, and the best form of fire nozzles. All of this apparatus should be constantly kept in good working order, for otherwise it may be found to be unserviceable just when most

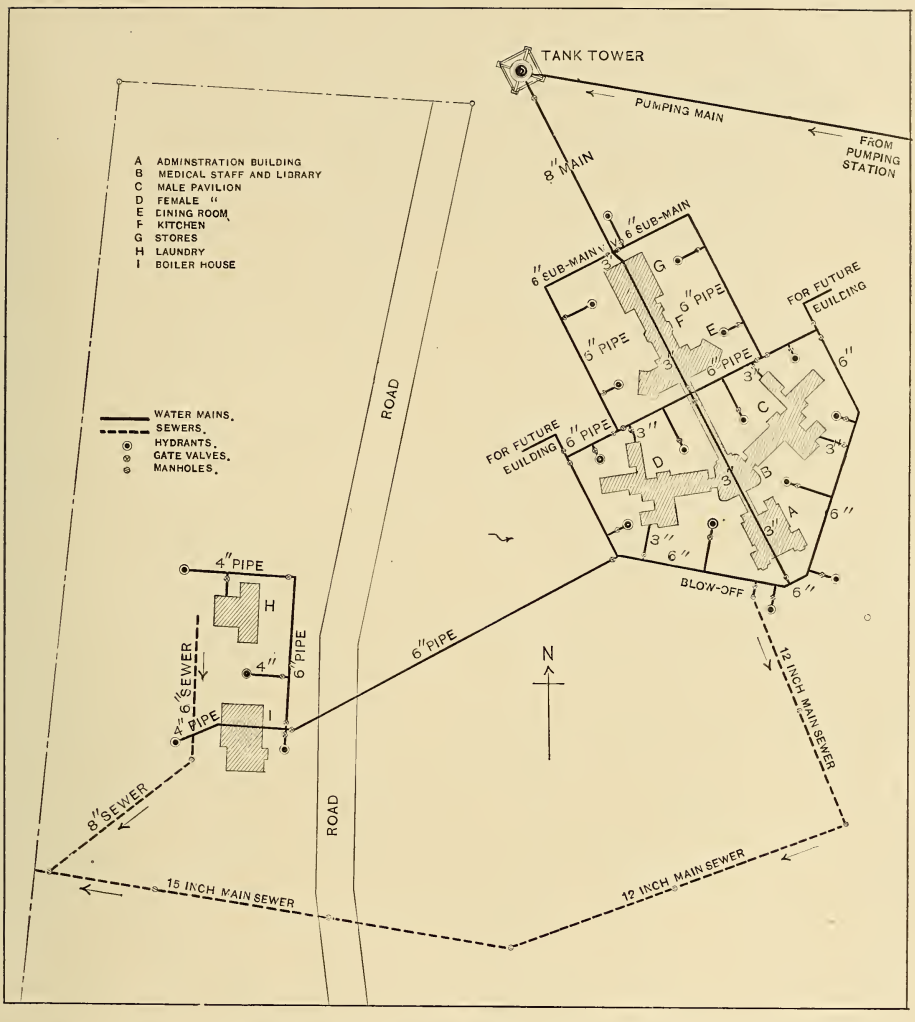


FIG. 46.—PLAN OF WATER SUPPLY AND SEWERAGE FOR THE STATE HOSPITAL FOR INSANE AT GOWANDA, NEW YORK

wanted. Not long ago, the writer was engaged to lay out the water supply of a country estate, comprising a fine mansion, a large stable and a gardener's lodge. With a view of providing some protection against fire he specified a large water supply main, with a number of outside fire hydrants located near the buildings. But when the cost of the proposed work was communicated to the owner, he called the writer a "fool" for making the suggestion, and the work was not carried out as planned. Some day this fine unprotected mansion, which is located several miles away from the nearest village fire engine house, may burn to the ground, and when that day comes the owner will have every reason to apply the above epithet to himself.

Fire hydrants and fire hose are useless unless an adequate storage of water under a suitable fire pressure is maintained. Where this is provided, it takes the place of the steam or hand fire engines of a fire department. In the case of large estates, having natu-

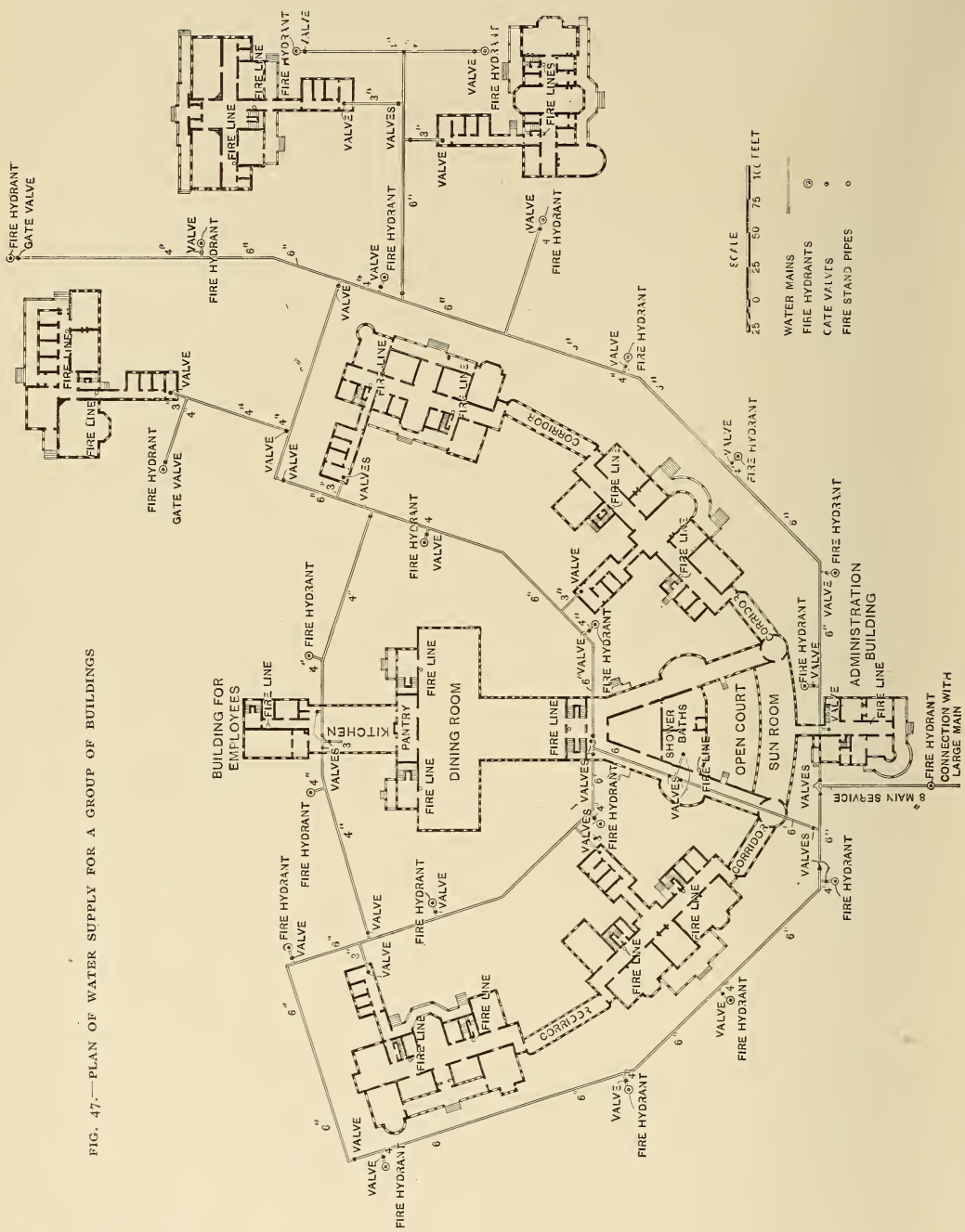


FIG. 47.—PLAN OF WATER SUPPLY FOR A GROUP OF BUILDINGS

ral or artificial lakes or ponds within the grounds, it may be practicable to keep on hand a portable steam or hand fire engine with sufficient and ample size fire hose, but this should only be regarded in the light of "auxiliary" fire protection. It is always better to install a fire protection equipment which is instantly available in case of need; with this in view, all fire apparatus should be kept in working order.

Regarding the inside fire protection, it may be pointed out that in country houses of two or three stories, having a house tank placed in the attic, the fire standpipe if supplied from it has an entirely insufficient pressure. Fire standpipes should therefore be connected with the outside main supplied from the elevated reservoir or tank. In the house there should be outlets with fire valves and fire hose on each floor. Plug cocks should not be used as fire valves, because after being installed for some time they set hard and are then very difficult to open. The highest quality linen fire hose should be purchased, and for inside use the unlined hose is recommended, being less liable to deterioration than the rubber-lined hose. In addition to the fire hose, a country house should have some fire pails and a few portable pneumatic or chemical extinguishers.

To illustrate the planning and laying-out of a water supply system for a larger institution, there are given in Figs. 46 and 47 the plans of several groups of buildings, the water supply distribution of which was arranged by the writer on the circulatory system. The sizes of the mains and laterals, and of the branches to the numerous fire hydrants, provided for the sake of protection from fire, are given in the plans. They also explain how it is possible, by means of the shut-off gate valves provided in a circulatory system, to keep any of the buildings supplied even if a part of the water main is temporarily shut off for repairs.

The Editor regrets that, through an oversight, the tank shown in Fig. 15, in Part II. of this article, in the May issue, was erroneously credited to A. J. Corcoran, when it should have been credited to the W. E. Caldwell Company, tank manufacturers, of Louisville, Ky.

MATHEMATICS IN ENGINEERING COLLEGES

By J. B. Stanwood

THIS article is not written to discuss the value of mathematics as a part of the training for an engineer, but to call attention to the fact that there is room for improvement in the methods of instruction in this important subject.

Most engineering graduates at the time of their entrance into active service are well trained in the use of mathematical forms and symbols; they can jostle and shuffle about with dexterity the equations and formulæ for deriving abstract values of x and y;—but in many cases these expressions convey to the mind of the manipulator no comprehensive or full idea of the relations that exist in fact among the values for which the symbols stand.

How many a graduate could express in English the equations that he employs, or state the logical steps by which his results are obtained? The process he uses consists in translating a problem into "mathematical short-hand,"—he follows a number of rules and processes in which he has been drilled and finally re-translates his results from the short-hand back into long-hand.

This is a valuable accomplishment, but perhaps five years after graduation with a career filled with more concrete and practical work, where there has not been continued practice in this branch of mathematics, he becomes so rusty that some bright office lad with a Trautwine, Kent or Unwin is as competent to secure accurate concrete results as he. And if a specially new or difficult problem arises, he will probably use some approximate method rather than brush up his calculus or analytics; or, if the nature of the case is such that these must be employed, our engineer, young or old, will hunt up some mathematical friend or expert for assistance in the emergency.

This may be the best thing to do, i. e., go to the specialist,—but as for engineering training in an engineering college where so much time is given to mathematics, should not the graduates have more power to use this valuable tool than they usually possess?

It may be argued that study of mathematics is in itself of great disciplinary value,—that it develops the power for close reasoning, for making clear analyses. This is true if properly taught, but the "short-hand" skill which forms so large a part of instruction is only a small part of the subject. It has its value for expressing results, rules, directions, etc., in a concise and clear way and contributes to saving time; but this skill is analogous to the skill which one may acquire in using a slide-rule,—it does not develop the mathematical sense.

"Mathematics deals with the relations of magnitudes," and the symbols which it employs are only to simplify and concisely represent these relations. The spirit should be worshiped,—not the letter.

A mathematical process may be divided roughly into four steps as follows:—

First. Forming a clear conception of the relations involved. Graphical representations usually assist materially in forming such conceptions.

Second. Expressing the relations as they exist by mathematical forms or equations.

Third. Treating these expressions mathematically so as to secure values of one magnitude in terms of one or more related magnitudes.

Fourth. Finding the concrete value of one magnitude corresponding to concrete values of one or more of the other related magnitudes.

College instruction spends the larger part of its energies upon the third step, and too little stress is laid on one, two and four. Were engineers given sufficient drill in these steps they would more likely maintain the skill which step three involves.

Someone may say that the text-books are full of matter which involves practice in the first two steps. This is true, and herein lies the difficulty; there is no original work or practice for the student along these lines,—all is worked or mapped out for him, and his duty is to read and comprehend and be ready to repeat in recitation or examination the processes he has been taught.

In modern geometry and algebra, the so-called original or concrete problems give the best training; they are to the subject matter what laboratory work is to chemistry or physics, requiring investigation, observation, discovery, invention and the study of the relation of all the parts. In higher mathematics there is usually little or none of this laboratory work.

Perhaps one reason for this lies in the fact that the instructor uses his mathematics but little in an applied way,—he has no concrete problems to solve day by day, and does not realise the difficulty to the student of the first two steps. The instructor follows and elucidates the text-book, and adheres closely to it, as it is logical and advances step by step. In practice, however, the steps have to be selected or discovered, and it is here the student needs special practice to develop skill and judgment.

Professor John Perry, of England, has worked out this phase of the subject thoroughly; his numerous books are, however, of more use to an instructor than to a student, as they are suggestive rather than logical, and are full of meaty problems. In the calculus for engineers he shows that there are but a few well-known forms of integration and differentiation which are useful to engineers, and by grouping under each a large number of applications taken from mechanics, strength of materials, dynamics, thermodynamics, electricity, etc., he gives an opportunity for a wide range of practice. Relations are obtained or tested from all sides, by curves on squared paper, by arithmetic, algebra, geometry, trigonometry, analytical geometry and calculus,—whichever is necessary and proper. The student is led to seek relations, old and new, to express them mathematically, to treat them mathematically, and to obtain concrete results.

Perhaps the difficulty with the college professor or instructor lies in the fact that the text-book he uses or has written is the fetish he worships. For some reasons, for the student's sake, it would be better if there were no text-books except as they may be used for reference.

The instruction could be given more efficiently by means of lectures, enough for elucidation and logical sequence, and by problems part of which are so selected as to develop a certain amount of original investigation. All assigned work should be worked out partly in the class-room under the instructor's eye, with frequent "quizzes," so that the student's method can be criticised and improved, and with a sufficient quantity outside of the class-room to develop self-reliance and independence.

In large institutions, the present system is such that the text-book is a necessary evil; it is used by the instructors under a professor of mathematics to keep the different classes and the students in each class "in step." The professor of mathematics does not know exactly what is going on in each section, and the instructors have little or no criticism from him of their methods of instruction or presentation. Results are only determined by tests or examinations. Would not something like the following plan, which is understood to be in vogue to a greater or less degree in some Ger-

man institutions, give better results?

The master, a professor of mathematics, a man of rounded practical and theoretical experience, has supreme control of the entire work in his department. Among his duties is that of delivering a course of lectures embracing the entire subject, applied and theoretical, in a broad and comprehensive spirit. Such a course begins with the freshmen and continues through all grades to the end of the mathematical work. Each year's class, perhaps 400 in number, attend these lectures once or twice a week. The master's lieutenants, the instructors, also attend in order to keep in touch with the master's scheme and methods; if necessary, too, they are to be assisted by regular private conferences.

The master assigns the work, presents the problems, investigations and analyses; in recitation this work is taken up and conducted as already indicated by the instructors. This recitation work if properly prepared can be the laboratory work of the student,—it should be adapted, as far as possible, along laboratory lines.

The master's duties through the week should include visits, as far as is possible, to the various recitations to keep in touch with the work of his instructors, and to guide them by his judicious and careful criticism, preferably given outside of the class-room. He thus becomes familiar with the difficulties of both students and instructors; he may find some instructor better adapted for one class of students than another, or better fitted for one branch of the work than another. He also comes more closely near to each student, so that all, the freshly arrived man as well as the advanced student, have an equal chance of securing some contact with his personality.

It lies in the master's hands to do with effect what Professor Rucker, a president of the British Association, recommends when he says:—"It is better that a student should be brought up rather rapidly to a point, and afterwards go into the various difficulties. Then he may be taught the various qualifications in order to protect it against all attack after the first general statement has been put before him."

The master, if the spirit of the institution will permit, should fraternise with masters in other branches, determine their mathematical needs, and should endeavour to prepare his subject with the view of making its use immediately available in all allied and applied subjects. His problems can be taken from their work, he can arrange his investigations and analyses to bear directly on their wants. He can materially reduce the friction and duplication of work which now so often reduces the efficiency of the combined teaching force.

With the right man, the amount of enthusiasm and interest that can be awakened, and the amount of original work, discovery and invention on the student's part that can be secured, is amazing.

Less stress should be placed on tests and examinations, and more on daily performance and team work, all of which may be made to come under the master's eye. Tests and examinations are proper and advantageous in their place, and for certain purposes they should not be discarded, but the laboratory method or regular daily performance is a fairer and more accurate basis for the estimation of scholarship.

Too much stress cannot be laid upon graphical methods of curves and plottings on squared paper to represent relations, observations, equations, etc. As an example, thermodynamics has been rescued from the garret of signs and symbols by the graphical entropy diagram. Professor Perry has shown the way, and the visualisation of mathematical relations makes many a knotty problem clear.

THE DEVELOPMENT OF CANADA

By James Douglas

THE article in the February number of this magazine, by George W. Colles, on "The Development of Canada," contains so much truth that it seems ungracious to point out minor errors; and it is so appreciative of Canada's future that it seems invidious to dissent from some of the strictures made on Canada's past. But Quebec was not "a flourishing town when the Pilgrim Fathers landed on Plymouth Rock." It was founded as a fur-trading post by Champlain in 1608, and it remained nothing better than a fur-trading post until after its restoration to France, in 1632.

When the "Mayflower" made its memorable voyage, though the Quebec post was thirteen years old, it contained only sixty souls; all New France had a population of only seventy-six in 1628; and the following year, after the capture of Quebec by Kirke, there wintered in Quebec about 117 persons, of whom 90 were English,—members of Kirke's expedition.

Emigration has never been congenial to the Frenchman, and even if the political and geographical inducements to leave the mother land for Canada had been greater, the children of France would have been slow to forsake her for homes in the wilderness. But the colonial policy of old France was as inimical to the independent, pushing emigrant as the climate of the New France was repellent to the dweller in the sunny South of Europe. The colonisation of New France originated with the government, which, in order to induce French traders to take the risk of exploring and peopling the valley of the St. Lawrence, gave them commercial privileges of a most monopolistic extent and kind, and endowed their organisations with the powers of government and most absolute administrative control. But as the traffic in furs was the only profitable trade, it was to the interest of the trading companies to repress rather than to encourage colonisation, and with it the destruction of the forests and the annihilation of the fur-bearing animals.

When at last France assumed the reins of colonial government, the Huguenot revolt in the mother country had been crushed, and Richelieu and his successors, warned by the excesses of the Commonwealth in England, and the independent, almost revolutionary, bearing of the neighbouring British colonists, excluded from New France not only heresy but every vestige of popular government. French domination therefore discouraged individuality, but nevertheless Frenchmen explored and hoisted the Fleur de Lis over the whole lake country, on the Ohio, on the Mississippi from its mouth to its sources, and over the Plains to the base of the Rocky Mountains. They did this while Englishmen were content to be

confined between the ocean and the Allegheny Mountains.

But just here, apart from the influence of race and political institutions, lies one reason for the slow growth of the French, and the rapid growth of the British colonies. The British were on their congenial element, the sea, and the trade of the world was open to them; and they entered and enjoyed it, despite the commercial restrictions imposed on them by the mother country. Canada, on the other hand, even if her people had been imbued with the commercial spirit, were shut off from the sea by 500 miles of dangerous river navigation, and absolutely blockaded from all intercourse with the world for six months by snow and ice. These climatic and geographical conditions handicapped old Canada, and they handicap the Dominion to-day, but they are being relieved by the railway.

Their influence is felt both in the backwardness of the country and in the character of the people. A community isolated for half the year from all commercial pursuits, gave itself over to amusement, learned to take life easily, and set more store on social enjoyment than on wealth. Old-world feudalism and the Church have left an indelible impression on the French of Quebec. While British loyalism and the Gælic immigration from the highlands of Scotland constitute the leaven of the original British population of the Dominion, these ingredients have not made a mixture of explosive energy; but they do constitute a very safe and sound foundation on which to build a nation; and a prosperous structure is being built up without much foreign admixture. The last census,—that of 1901,—shows that of the total population of 5,371,315 souls, 4,671,815 were Canada born, and, of the foreign born, 94.6 per cent. were British, and only 5.4 from the Continent of Europe or the United States.

It is true, as Mr. Colles remarks, that "the thing that most strikes the attention as one passes the boundary line from the United States into Canada is the abrupt transition from a state of bustle and activity to a leisurely and provincial existence; compare, for example, the neighbouring cities of New York and Montreal, Buffalo and Toronto, Detroit and Windsor."

He then draws comparisons between Massachusetts and Nova Scotia. Comparisons should really be drawn between contiguous territories, say between New Brunswick and Maine. The Canadian census of 1901 shows that New Brunswick gained during the previous dicennial period 3.06 per cent., while Maine gained 5.0 per cent., but Vermont gained only 3.4 per cent. in population, or very little more than New Brunswick, and not nearly so much as the contiguous province of Quebec, whose population increased during the same interval 10.77 per cent.

Boston and Montreal are fit subjects for comparison. The last United States census shows a growth of 25 per cent. for the capital of Massachusetts, and the Canadian census for the corresponding period shows that Montreal grew 22 per cent. Turning to the West, the greatest growth in any one of the American Prairie States was in North Dakota, namely, 67.01 per cent., which was almost exactly the same as that of the neighbouring province of Manitoba; but the Western territories of Canada, with their vast stretches of tempting unoccupied land, more than doubled their population between 1891 and 1901.

There is no gainsaying the disadvantage under which the older provinces of Canada labour of possessing only a narrow fringe of attractive productive agricultural land on the St. Lawrence, and to the north of the lakes, if we except the rich and very prosperous peninsula of Ontario. The great Northwest was inaccessible until reached by the Canadian Pacific Railway. It is now being peopled more

rapidly than any section of the Dominion except British Columbia, which province, under the impulse of mining, nearly doubled her population during the last census period.

It has been under the stimulus of railways that Canada's rapid progress has of late been made, but her railway system has heretofore clung to the populous banks of her waterways, or, while crossing the plains, has kept as far to the south as possible. Now a bolder policy is to be pursued. The Grand Trunk Pacific will run from Quebec to Fort Simpson, on the Pacific coast, keeping through Ontario to the south of the height of land between the lakes and Hudson Bay. Fort Simpson is about 400 miles north of the present terminus of the Canadian Pacific.

Another line is also being built; the Trans-Canadian Railway, as an extension of the Lake St. John Railroad from Quebec, which will skirt Hudson Bay and join the Grand Trunk Pacific at Norway House at the discharge of Lake Winnepeg. Meanwhile, a third line, the McKenzie & Mann road, has already opened up the country between Fort William on Lake Superior and Winnipeg south of the Canadian Pacific, and is being built so as to develop the new provinces about to be given virtual statehood, lying between the Canadian Pacific and the projected Grand Trunk Pacific. These new roads will traverse a territory quite as large as the Middle West, of the United States.

Nevertheless, the railways of Canada, though they have hardly penetrated the inhospitable interior of the Eastern section, and have exposed only a thin section of the Rocky Mountain chain, have aided mining almost as sensitively as have those of the United States. Canada has 19,033 miles of steam railway. The United States has 203,132. The mineral product of Canada, including both metallic and non-metallic minerals, had a value in 1903 of $63,600,000, or $3281 per mile of railway, while those of the United States were valued at $1,419,721,000, or $6989 per mile of railway.

The mineral production of Canada per head of population bears a similar relation to that of the United States, namely, $10.40 for Canada, as against $20 per head on the American side; but when the greater value of the product on this latter side is taken into account, the calculation based on quantities instead of values reduces largely the balance of advantage on the side of the United States.

Mr. Colles' enthusiasm over the immense area of more than 3 million square miles of undeveloped and even inhospitable territory, underlaid by mineral-bearing rocks, is warranted and may well excite speculation as to Canada's future, more especially when we recall the progress in Alaska as soon as the gold discoveries were made in the Klondyke. This vast unknown Canadian territory lies, most of it, it is true, within the Arctic Circle, but so does Northern Alaska; yet actual experience has recently dispelled many of the fallacies bred of ignorance regarding its climate. Moreover, the largest iron deposits of the world, those of Swedish Finland, are being worked winter and summer, though almost on the parallel of the Midnight Sun.

The new Grand Trunk Pacific Railway will reach within 400 miles of the navigable waters of the Slave River and the Mackenzie, and therefore many years will not elapse before not only the vast oil fields of that region, but its mineral resources will be within striking distance of the industrial centers of the world, for the Mackenzie and Slave rivers are navigable for twelve hundred miles from the sea, and are clear of ice from the beginning of June to the middle of October.

TYPES OF CENTRIFUGAL PUMPS

By Wm. O. Webber

IT is, perhaps, not generally known to the average reader that great improvements have been made in centrifugal pumping in the last decade, previous to which very little advance had been made for a long time; in fact, the capabilities of centrifugal pumping seem to have been universally neglected.

Centrifugal pumps were known as early as the seventeenth century. Papin, the celebrated French engineer, designed a centrifugal pump in 1703. Euler brought out a pump of this type in 1754. In 1818 a form of centrifugal pump was brought out in Massachusetts, U. S. A., known as the Massachusetts pump. In 1830, a Mr. McCarthy erected a pump in the New York Navy Yard, which was credited to have approached the efficiencies of the present day. In 1846 Andrews produced pumps of this type and about the same time John and Henry Gwynne, in England, commenced the manufacture of centrifugal pumps as a commercial enterprise. Appold exhibited a model of a centrifugal pump at Birmingham in 1849, and at the Crystal Palace Exposition in London, in 1851, Appold's pumps were an important feature.

All of the pumps above referred to had a single impeller or runner. Some of these pumps had the suction upon one side only, and some, like the Massachusetts and Gwynne pumps, had double suction inlets or openings on both sides. All of these pumps were made for comparatively low lifts and large quantities of water and did not have very high efficiencies.

From 46 per cent. to 64 per cent. seems to have been the best result obtained with pumps of this type under heads varying from $4\frac{1}{2}$ to 15 feet. The pumps were directly connected to steam engines, and duties of from five and one-half million to forty-eight million foot-pounds to 100 pounds of fuel were obtained. Forty feet were formerly considered the maximum height at which centrifugal pumps could operate efficiently. Experiments of the writer, conducted in 1874, 1875 and 1876, seemed to demonstrate that the highest efficiency in the single-stage pump was found at a height of about 32 feet, and at a maximum velocity of the liquid being pumped through the discharge orifice of the pump, of not more than 12 feet per second.

Appold in his experiments determined that the efficiency depended mainly upon the form of the blades of the impeller or vane and the shape of the volute or enveloping case, and that the best form for the blade was a curve, pointing in the opposite direction to that in which the impeller revolved, and for the case, that of a spiral tapering type or volute.

The first engineer who seems to have discovered the value of compounding centrifugal pumps, that is, causing the discharge of one centrifugal pump, either integrally formed or simply in close juxtaposition, to be led into the suction of another similar pump, was the Swiss engineer, Sulzer, of Winterthur.

He was pretty closely followed by A. C. E. Rateau, of Paris, France, and John Richards and Byron Jackson, of San Francisco, Cal. All the pumps designed by these men were constructed originally with the impellers facing in one direction, and the consequent thrust upon the impellers was partially taken up by balancing chambers upon the rear of each impeller.

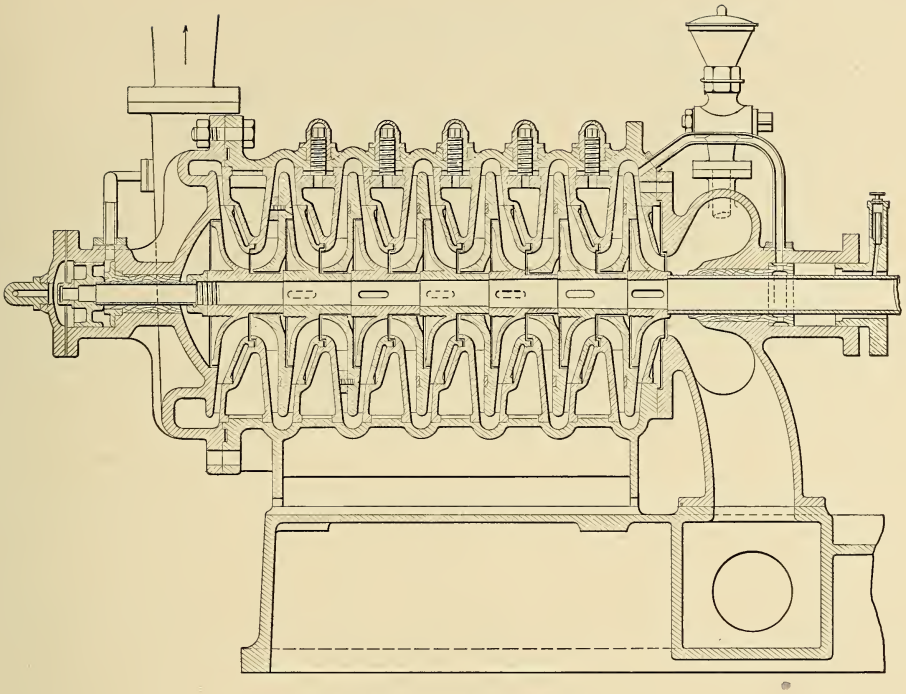


FIG. 1.—BALANCING RATEAU'S PUMP

This form of balancing was further improved in Rateau's pump by a balancing cylinder at the extreme discharge end of the pump shaft, into which water was admitted from the discharge orifice of the pump. This is clearly shown in Fig. 1. Rateau further attempted to improve the balancing of his pump by constructing inclosed impellers, having one of the side plates of the impellers of smaller diameter than the other so that the areas of the two impeller side plates subjected to the discharge pressure from that impeller were equal. This will be understood from Fig. 2. The diameter *D* is enough smaller than the diameter *E*, so that the area of the side plates under discharge pressure at *a* will be equal to the area under discharge pressure at *b*

Fig. 2 also shows a balancing piston *c*, with a pipe *d* leading from the discharge of the pump to the opposite side of that shown in Fig. 1. In this case Rateau seems to have overbalanced his pump in the opposite di-

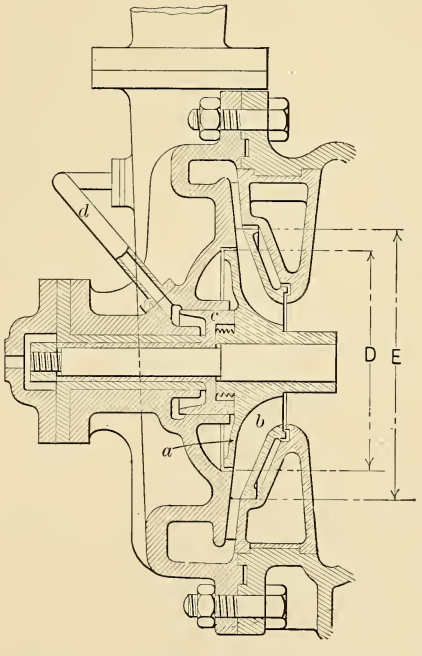


FIG. 2.—BALANCING RATEAU'S PUMP

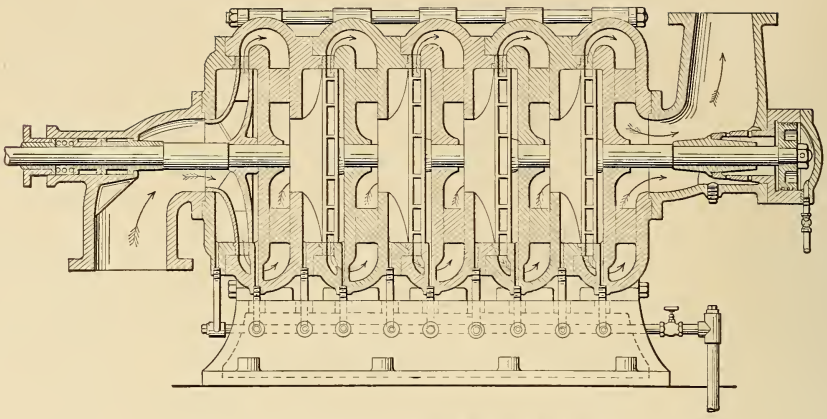


FIG. 3.—BALANCING THE RICHARDS PUMP

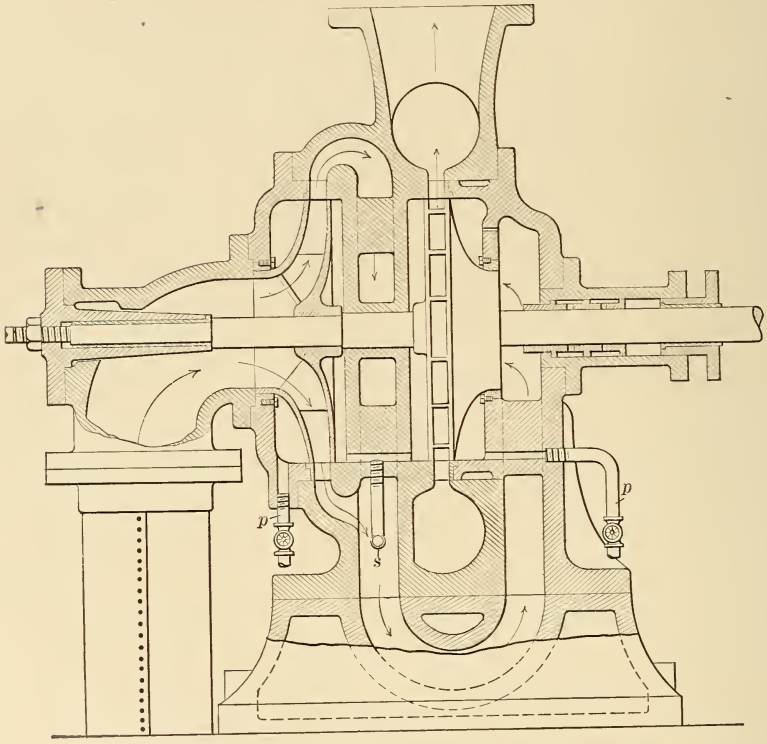


FIG. 4.—ANOTHER METHOD OF BALANCING THE RICHARDS PUMP

rection from that obtaining in Fig. 1. In fact all of these devices seem to show a decided uncertainty as to the direction in which the balancing would finally have to be applied, and provisions were made to adjust this balancing as each individual case required under existing conditions, which still further emphasizes the fact, that it is better construction to make a pump which will be in mechanical balance itself under all conditions.

John Richards also used a balancing piston at the discharge end of

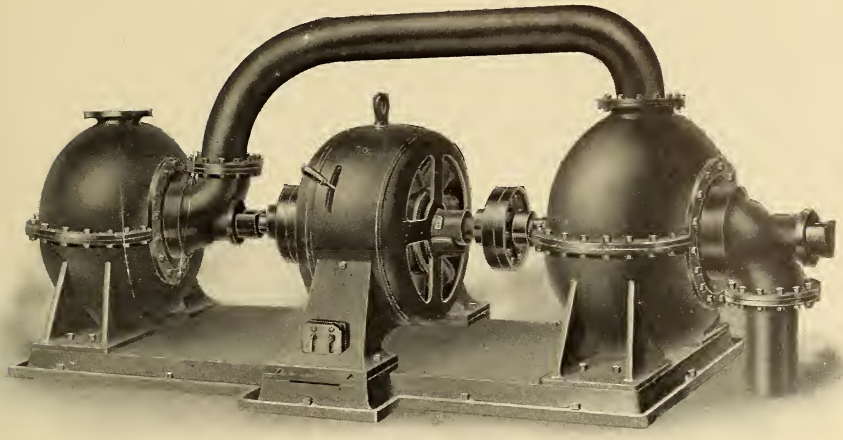


FIG. 7.—TWO FIVE-INCH FOUR-STAGE SPHERICAL COMPOUND PUMPS, COUPLED IN SERIES, WITH MOTOR BETWEEN. CAPACITY, 750 GALLONS PER MINUTE TO HEIGHT OF 1200 FEET, FOR DEEP MINE AND EXTRA HEAVY PRESSURE SERVICE. MADE BY THE LAWRENCE MACHINE CO., LAWRENCE, MASS., U. S. A,

the pump, directly connected with the discharge pressure, as shown in Fig. 3; and also attempted to further balance a pump of this type by exhausting the air from one side of the impeller and forcing air in upon the other side. This is illustrated in Fig. 4, in which the pipes *pp* are under pressure preferably by being connected to the discharge of the pump, forcing water onto the inlet side of the impeller, and exhausting the pressure through the pipe *s* by putting it into the suction of the second impeller, so as to produce a partial vacuum upon the sides of the impeller opposite from the suction.

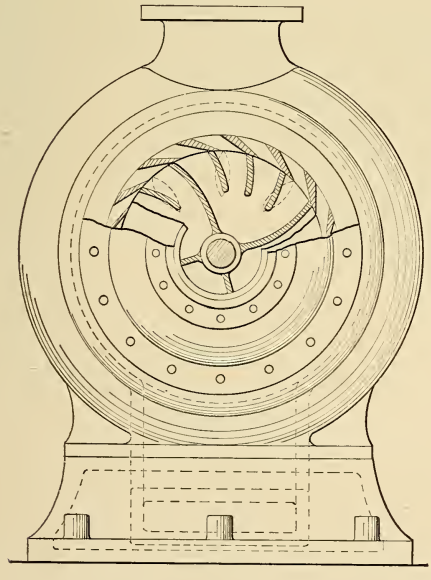


FIG. 5.—REMOVABLE DIFFUSION VANES IN THE RICHARDS PUMP

Another method of balancing the end thrust of centrifugal pumps was by false vanes located upon the outside of the side plates of an inclosed impeller, these being designed to relieve the pressure upon the outside of such impellers by establishing a counterflow through the place around the periphery of the impeller and causing a partial vacuum to exist. By making these false vanes of different radial lengths on the opposite sides of the impeller, the end thrust can be counteracted for any given set of conditions, but it is not believed that a pump thus provided with balancing vanes will remain in good operative balance if the original conditions are changed.

These diffusion vanes, which form a distinguishing feature of the turbine type of pump, are located in the usual whirlpool chamber of the centrifugal pump in such a manner as to change

the flow of the water, which leaves the impellers at a high tangential velocity, into a direct radial flow. This also has the effect of overcoming the eddies formed by the water leaving the impeller, thereby reducing internal friction.

This construction, therefore, causes a centrifugal pump to assume the converse of a turbine water wheel. The direct radial flow becomes of great importance in compound centrifugal pumps where the liquid being pumped is to be passed from one impeller to another. Many different forms of these diffusion vanes have been devised, and John Richards seems to have been the first one to form them

balancing of compound pumps by placing the impellers back to back in pairs, so that one impeller thrust in one direction and the next one in the opposite direction. The method which he followed, however, of conveying the liquid being pumped from one impeller to the next, required short, tortuous passages, as he utilised the fixed guides of the whirlpool space of the pump to form these cross-over passages; it is believed also that to Sulzer we are indebted for the idea of introducing the guide blade or turbine element.

John Richards followed Sulzer in placing two impellers back to back and differed from Sulzer in passing

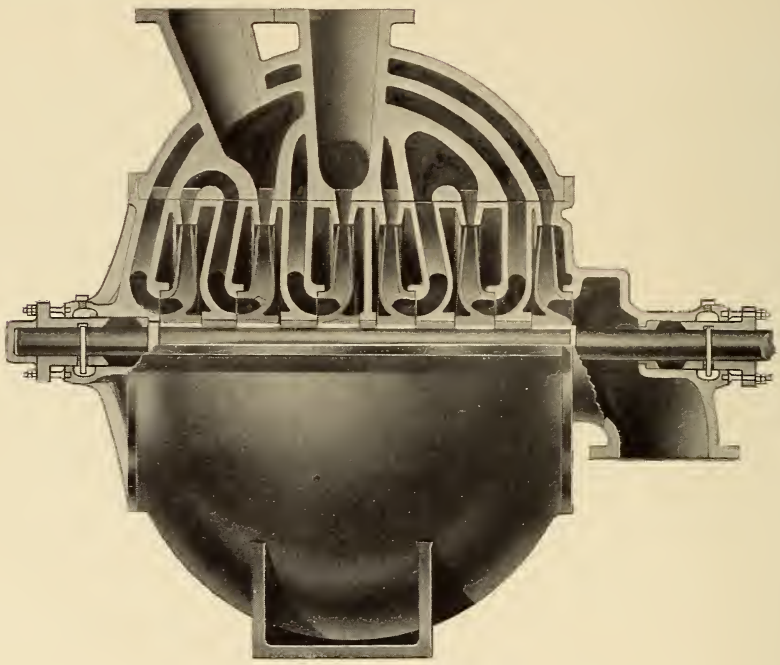


FIG. 6.—HALF SECTION AND ELEVATION OF A SIX-INCH SIX-STAGE "SPHERICAL" COMPOUND PUMP WITH TWO OUTLETS. MADE BY THE LAWRENCE MACHINE COMPANY

in a removable annular ring surrounding the impeller, and as these parts are subject to considerable wear, their removal and replacement are thus rendered convenient and inexpensive. Fig. 5 illustrates this.

Sulzer made the greatest step in the

the discharge from one impeller out and around the discharge chamber of the final impeller, but showed this construction only in a two-stage pump.

Hochdruck and Sulzer both locate their impellers back to back in pairs and pass the liquid from one impeller

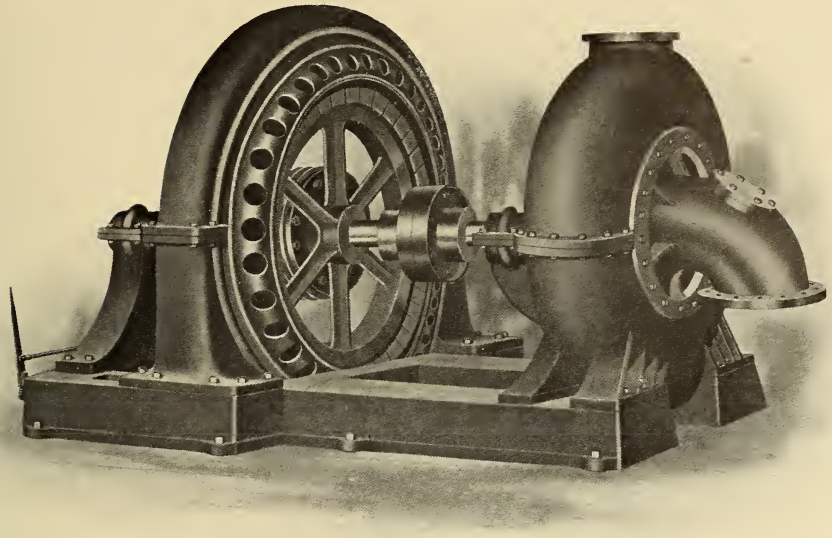


FIG. 8.—SPHERICAL, ELECTRICALLY-DRIVEN LAWRENCE COMPOUND WATER WORKS PUMP. CAPACITY, 30,000,000 GALLONS IN 24 HOURS AGAINST A 173-FOOT HEAD. THE 1400-H. P. THREE-PHASE MOTOR IS DIRECT CONNECTED

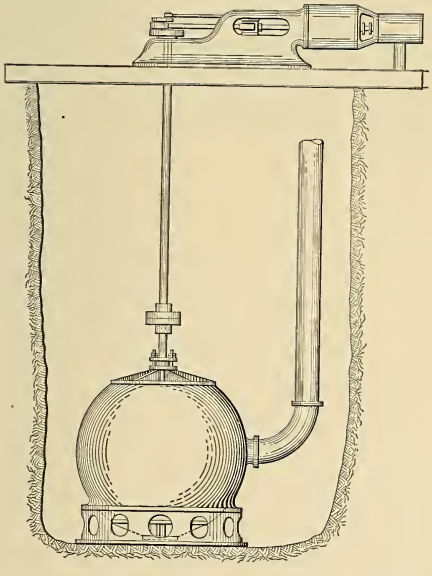


FIG. 9.—A VERTICAL TURBINE PUMP FOR UNWATERING A SHAFT, DRIVEN BY A HORIZONTAL ENGINE

through lateral passages located between the radial vanes of the stationary guides surrounding the peripheries of each pair of impellers. In this form of construction, while the sum of the discharge pressures in one direction balances the sum of the discharge of the opposite direction, any variation in the suction pressures will throw such a pump out of balance.

This is evidenced in that all of the constructions of Sulzer, Richards, Rateau and others show a thrust bearing and balancing piston at the discharge end of their pumps, which they have specifically stated was put there for the purpose of overcoming the residual thrust.

It is the opinion of the writer that in a properly constructed pump no thrust, residual or otherwise, should be left over or unbalanced, and he believes that he is the first one to design an absolutely balanced compound centrifugal pump, by causing the impellers to be placed back to back, but not in pairs serially disposed; and in producing results from the method in which he sequentially connects the different impellers, so that both the sum and difference of the suction and discharge pressures of all the impellers in any compound centrifugal

pump equalise and balance each other.

Some of these different types of pumps may be of interest here. Fig. 6 shows a half section of one of the writer's six-stage compound pumps.

Fig. 7 shows two spherical compound pumps coupled in series for very high lifts, the motor in the centre driving both pumps at a constant speed, the second pump of the series being made practically twice as heavy as the first pump of the series, which takes the water practically under no pressure.

Fig. 8 shows a very large two-stage spherical pump, directly connected to a 1400-H. P. alternating-current generator used as a motor.

Fig. 9 represents a vertical turbine pump in the bottom of a shaft, directly connected by a vertical shaft to a horizontal, tandem-compound steam engine, with vertical pillow-block bearing.

Current Topics

The extraction of gold from sea-water electrically has again been seriously proposed, this time by "The Lancet," London. "The Lancet" claims to have suggested more than eight years ago that the announcement that definite quantities of gold had been recovered from sea-water would be sure to attract the attention of speculators. Estimating that one ton of sea-water contains approximately one grain, each cubic mile of sea-water will contain approximately two hundred tons of gold,—a truly attractive prospect to the company promoter, as "The Lancet" remarks; and in fact it learns that a serious attempt to wrest a proportion of this vast wealth from the sea by means of electricity is about to be made by a company somewhere on the south coast of England. "The Lancet," in this matter, affords a striking illustration of the wisdom of the old proverb, "Let the shoemaker stick to his last," when it makes what it considers the eminently practical suggestion that a couple of copper plates be suspended in the sea from the sides of the great trans-Atlantic liners, and supplied with current from the ship dynamos, for the purpose of collecting the gold contained in the sea-water, during the voyage. To those familiar with the precautions necessary as to density, electrical resistance, etc., of the electrolyte, strength and electromotive force of current, etc., in electri-

cal gold deposition, the simplicity or prospective success of the proposed experiment is not so apparent. Besides it seems to have been forgotten, that not a great many years ago a company was organized for this same purpose in America. The company succeeded in extracting a great deal of gold from the pockets of many gullible investors in the stock of the company, but so far as known very little was extracted from the sea-water. A little sober reflection should make it perfectly clear to anyone that the cost of electrolysing 11,520,000 parts of sea-water to deposit one part of gold would be prohibitory, as it has been found to be in actual practice. The matter of keeping a pair of "copper plates" in juxtaposition in the water on the side of a ship during a trans-Atlantic voyage is evidently not considered to present any difficulty. Try it. The fact that electrolytic action is proportional to the current, and that special dynamo machines of very low electromotive force and very heavy current output would be required on board ship in any practical attempt to extract a metal from its salts, is also obviously overlooked.

The recent sessions at Washington, D. C., of the International Railway Congress of 1905 having been concluded, it is natural to think of the results of this great gathering of transportation experts from all quarters of the globe. Doubtless several years will pass before the travelling public will feel the effect of any marked changes in railway operation traceable to the stimulus of the past two or three weeks. At the same time there is good reason to believe that the Congress marks an important forward step in the transportation world, and that its educational value to the progressive railway man has been considerable. From the operating standpoint, the most significant undercurrent in the atmosphere of the Washington meeting was the insistence of electricity in its claims for due recognition as the ideal motive power for handling suburban and other dense traffic. Although, with the exception of elevated railways, the United States has yet no example of an electrified steam road in operation, the influence of the great terminal changes in progress at New York and the readiness of the manufacturing companies to undertake the huge task of revolutionising with the electric motor the suburban service of the modern large city were signs of the times too powerful to be overlooked. The interest of the delegates in the electrical problem was evident both at the regular sessions and at the splendid exhibit of railway appliances held at Washington coincidently with the Congress, and this interest was sustained as the delegates journeyed about the country. As in other professional conventions embracing many countries, the delegates enjoyed to the full the broadening advantages of mutual intercourse at close range. In the widest sense the appreciation of foreign points of view thus gained and the toleration of divergent opinions resulting are the most important fruits of such a cosmopolitan assemblage of educated minds. Beyond the detailed knowledge of new methods and appliances so freely offered, stands this cementing of friendly relations between representative citizens of the different nationalities in attendance, with its influence toward peace through a better understanding of the diversities of world-wide human activities. In such ways as this the advance of civilisation is encouraged.

To a user of compressed air who complains of trouble from freezing up of an air pipe-line, which in this particular case is exposed, "Compressed Air" says that the only reliable way to prevent such freezing is to eliminate the moisture in the

compressed air before it enters the pipe line. This is best done by use of an after-cooler, which is simply a tank containing a nest of tubes placed closely together. The air passing on the outside of the tubes is broken up into thin layers and the water circulating through the tubes effectively cools the temperature of the air, so that practically all of the moisture held in suspension is dropped to the bottom of the cooler. An after-cooler can be secured from any compressor manufacturer, or one could be made up from an old tubular boiler which would probably answer the purpose. It would also be a good plan to place the air receiver out of doors, provided it would not be too far from the compressor cylinder, say 20 to 25 feet. This arrangement would probably take most of the moisture from the air.

What is commonly designated as "business management," said Henry R. Towne, in a recent address at Purdue University, is the final factor in the success of nearly every business in the field of industrial production. In some it is dominating. For example, in the industry of sugar refining the cost of refining raw sugar in well-equipped modern refineries is less than $\frac{1}{8}$ of a cent a pound, while the fluctuation, both in the price of raw sugar and of the refined product, may be 1, 2, or even 3 cents a pound in the course of a year or two. In other words, the entire cost of manufacture is insignificant in comparison with the market fluctuations in the value of raw material and of the finished product. In such a case success depends chiefly on business management. Undoubtedly that is an extreme example, but in nearly all industrial undertakings the factor of business management is of vital importance; its influence is always great, and often is controlling. A good engineer ought also to be a good business man. If he is not, it is a question if he can ever, in the fullest sense of the word, be a good engineer. Both require common sense, and habits of clear thinking and thoroughness.

The advantages of electric heating in many phases of human activity on land have of late been widely recognised, but the peculiar facility with which the electric current can be employed on shipboard for heating service is not so well appreciated. It is not too much to say that every characteristic of the electric heater which commends it on shore is emphasised with peculiar force in marine work, where compactness is of vital importance, weight at a premium, cleanliness and convenience are prime objects, and safety is paramount. Thus, the last built steamers of the Cromwell Line, together with the "Oceanic," "Celtic," "Cedric," and other mammoth trans-Atlantic liners, have all their upper deck staterooms heated by electric radiators; electric griddles and broilers, laundry irons and hot-water urns have made their way into the galleys of many fast ships; while for stateroom service, electric heating pads, once used, are almost indispensable in cases of illness. The Hamburg-American and the North German Lloyd lines have been completely equipped with electric curling-iron heaters and electric food warmers, and extending use is being made by them of electric radiators. The private yacht also offers an attractive field for the introduction of electric heating. The slight additional cost is far outweighed in such cases by the comfort and convenience of an electrical installation. The ease with which electric wires may be installed in comparison with the expense and difficulty of supplying steam connections is a strong point of advantage. No heat is wasted, the fire risk is greatly reduced with approved workmanship and materials, and the coolness, flexibility and free-

dom from disagreeable odours, dirt, oil and grease are cardinal points of favour in the eyes of yacht owners.

The scaling up of water pipes and jackets is quite as likely to happen as that of boilers, but it seems to be less frequently thought of as a cause of trouble. Water jackets on gas-engine cylinders are known in many instances to have become thoroughly clogged with mud and scale, with overheating as the result, and only recently a case was recorded where a boiler feed pipe had to be taken down and cleaned out before the feed pump could be made to run at its old-time speed.

One of the world's fuel reserves which until very recently received comparatively little attention, with all the talk there has been of exhaustion of coal beds, is found in the form of peat. According to John Clark Hawkshaw, in a presidential address before the Institution of Civil Engineers about two years ago, the most productive area for peat is North Germany and the adjoining parts of Denmark and Holland. In Friesland there are bogs 1500 square miles in extent, and Germany has more fuel in peat than in coal. A square mile of bog 10 feet deep contains peat equal in heating-power to more than 300,000 tons of coal. Ireland has 1,000,000 acres of large bogs 10 feet to 30 feet deep. The bog of Allan alone has an area of 372 square miles, with an average depth of 25 feet. In Sweden, where peat is used more largely than in other countries, a crown peat engineer has been appointed. It is estimated that the Swedish bogs would yield an equivalent of 3000 million tons of coal. In Central Sweden as much as 1,000,000 tons of peat is prepared annually, chiefly for metallurgical purposes. For years peat has been used in Siemens steel and glass furnaces; and in Finland, Russia, and Germany, locomotive boilers are fired with it. It has been proposed to use peat fuel for electric power stations in Germany. It has been manufactured for fuel for many years, and much ingenuity has been displayed in devising machines for preparing peat fuel. In Germany peat pulp has been treated like paper pulp, being delivered in thin sheets on rollers to drying cylinders. The briquettes made in this way have not much less heating power than coal.

GEORGE HALE BARRUS

A BIOGRAPHICAL SKETCH

THERE are few mechanical engineers who occupy a more prominent position in the eyes of the engineering public, especially in the line of steam boiler and engine testing, than George H. Barrus, of whom an excellent portrait is presented in this issue. Mr. Barrus is one of that class of engineers, too small a class, be it said, who believes that a professional man owes something to his profession. If worthy to bear the name of engineer, the profession of engineering should be the wiser for his having contributed something of his effort and experience to the general store of engineering knowledge.

Acting upon that belief, Mr. Barrus several years ago compiled in book form the records of some of the leading boiler trials he had conducted, and at the same time drew from them the

lessons they taught him regarding steam engineering as applied to boiler work. The trials were made on about seventy different boilers and forty different types, and as all was original work done by Mr. Barrus, the undertaking was unique, both in conception and in execution. A few years later he brought out a similar compilation of engine tests which he had conducted, and both volumes are among the best modern contributions to engineering literature.

Much of this literature at the present time is in the shape of compilations and discussion of the work done by others than the authors, and no doubt it is all very good, in its way. But the importance of the volumes published by Mr. Barrus lies in the fact that the data of which they treat are wholly original with him, and there are no other books extant from the pen of an engineer of which this can be said. Mr. Barrus has thus set the example to his fellows to publish to the world what they have found out in their professions, and we hope that he will not only follow up these volumes with others covering the time since his "Boiler Tests" and "Engine Tests" were published, but that they may prove incentives to other engineers to tell the engineering world what they have accomplished for its benefit.

Most men who attain success in life, whether in one calling or another, have the right qualifications born in them at the start, and if these are properly trained, success is bound to come. Mr. Barrus may be said to be a natural-born engineer. He inherited a taste for mechanics from his grandfather, who operated a small saw mill and wood-working shop run by water power in his native village, Goshen, Mass. Many a day, at the early age of not more than eight years, did he spend in this mill, watching and studying its operations with deepest interest.

Later he manifested so much fondness and aptitude in using hand tools about the house, that his father provided him with a stock of carpenter's and cabinet maker's tools. With these he amused himself in leisure hours working at the bench, constructing a number of very creditable pieces of cabinet furniture. To enlarge the scope of this work he designed and constructed a jig saw worked by foot power, and with this built many ornaments in the line of wall brackets. He also planned and built a turning lathe and became quite expert in wood turning.

In studying physics during his early college life he heard something of the Bell telephone, then just being exploited. Skeptical whether such a thing would work, he got together some magnets, diaphragms, spools and coils of fine silk-covered wire, then turned up suitable wooden handles in his lathe, assembled the parts in the now familiar form of the telephone receiver, placed two of these receivers in different rooms some distance from each other, and connected them with wires, with the result that conversation was carried on between them at the very first trial.

About the same time his studies led to the telegraph. He conceived the idea of installing a telegraph line between his own house and that of a friend and classmate a few hundred feet distant. No sooner conceived, than he set about the work, and in a short time he had a complete outfit of batteries, sounders, keys, line, and galvanometers, and all the parts were constructed and erected by his own hands. Then he and his friend learned the Morse alphabet, and afterwards for a long time amused themselves in sending telegraphic messages.

In connection with this work young Barrus accomplished what he always regarded as a somewhat remarkable feat. He made all the brass castings required for the telegraph apparatus himself. First he built a moulder's flask and obtained the needed sand from a foundry in an adjoining town. Then he converted his mother's parlor stove into a brass furnace, first protecting the carpeted floor by a suitable

covering of lumber and plank. Obtaining a crucible and scraps of brass, he put them into the fire-pot and heated the stove red hot, endangering not a little the safety of the house; but he succeeded in melting the brass. The metal was poured into the moulds and the castings came out all right. In this crude way, too, by the use of proper patterns and cores which he had himself constructed, he made the casting of a small steam engine cylinder. He also adapted his turning lathe so as to face off the flanges, preparatory to building a complete engine.

Mr. Barrus received his early education in the public schools of Reading, Mass., graduating from the High School of that town in 1870, and in the same year entered the Massachusetts Institute of Technology, being then 16 years of age. He took the regular course in mechanical engineering, and graduated in 1874 with the degree of Bachelor of Science. His work at college was marked by close application to his studies and excellent standing. On the final examinations his percentage averaged one of the highest of his class, and in many of the studies relating to mathematics, in which he was especially proficient, his score was 100 per cent.

During the summer vacation of 1872 he was employed to assist the board of experts who made the duty trial of the famous Leavitt pumping engine at Lynn, Mass., and during that trial he had the somewhat easy, though important, task of weighing the coal. This was the first test with which it was his fortune to be connected. On that occasion also he was initiated into the mysteries of the steam engine indicator, and for the first time took an indicator diagram. It is interesting to mention right here that last year, thirty-two years after the time noted, Mr. Barrus was himself employed professionally by the Lynn Water Board for the purpose of examining the very same engine and advising in regard to rebuilding it.

During another summer vacation, while a student at the Massachusetts Institute, he was employed by the city engineer of Boston to superintend the construction of a wharf at Deer Island and another at Gallup's Island in Boston harbour.

Directly after graduation, Mr. Barrus entered the employment of Mr. Geo. B. Dixwell, through Professor Channing Whitaker, who was then in charge of the Mechanical Engineering Department of the Institute. Mr. Dixwell was a retired merchant, who had spent many years in China as the representative of Augustine Heard & Company. He had read and studied the reports of Chief Engineer B. F. Isherwood in his "Experimental Researches in Steam Engineering" on the use of superheated steam in some of the ships of the United States Navy, and thereupon devised a scheme for using superheated steam with safety to the cylinder by varying the superheat according to the cut-off. For the purpose of putting his ideas to a practical test he installed an engine and superheating apparatus at the Massachusetts Institute of Technology, together with a complete line of testing apparatus, and made a present of it to the Institute after his work was completed, so that it might serve as a steam engineering laboratory for instructing the mechanical engineering students of the Institute. This plant became the foundation of the first college steam laboratory in this country. Mr. Barrus was engaged first by Professor Whitaker as his assistant in immediate charge of the installation of the plant, and later he became Mr. Dixwell's engineer for conducting the tests and carrying on the investigations connected with the work.

During this engagement, Mr. Barrus devised a cylinder pyrometer for showing cylinder temperatures when using superheated steam. This instrument was so sensitive and effective when working in saturated steam engines that it registered the changes in temperature within the cylinder which alternately rises and falls dur-

ing the cycle of operations constituting a double stroke. While filling the same engagement, he devised a continuous calorimeter for measuring the amount of moisture in steam, the apparatus described in Vol. VI, 1884, of the "Transactions of the American Society of Mechanical Engineers." This device works on the principle of the surface condenser.

The superheating investigations led to the appointment of a board of United States Navy engineers,—Chief Engineers Loring, Baker and Farmer,—to test the Dixwell system, and these gentlemen convened in Boston and used the Massachusetts Institute plant for their work, which consisted of a series of tests made with both superheated and saturated steam. Although under the direction of this board, the actual work of the tests was carried on by Mr. Barrus and his assistants. Before the tests were completed, Chief Engineer Loring complimented Mr. Barrus on the ability he displayed, and advised him to go into the Navy. At the same time, he volunteered to state that he, together with Messrs. Baker and Farmer, would gladly make a joint recommendation to the board of examiners, and thus assist him in securing an appointment. Although he did not avail himself of this offer, Mr. Barrus considered that such a compliment from one who afterward became the chief of the Bureau of Steam Engineering of the United States Navy, was of signal value, and those who know the care and fidelity which have characterised Mr. Barrus' testing work in later years can understand how well the compliment was deserved. These tests were made in 1877.

During the next two years, Mr. Barrus installed the Dixwell apparatus at the works of the Pratt & Whitney Company, at Hartford, Conn., and later put in a plant at the American Institute in New York, where he exhibited it at one of the Institute's fairs. At both places he conducted tests and obtained data on superheated steam which proved of much value. The engagement with Mr. Dixwell closed in 1880, and at that time Mr. Barrus opened an office in Boston and started in business for himself as an expert in steam engineering. He had already attained some reputation as an expert, his connection with the Massachusetts Institute Steam Laboratory having become known, and various clients had from time to time secured his services. There was a field for his work, and as soon as he had become established, plenty of business awaited him, and for the most part it came unsolicited.

A layman in steam engineering matters may wonder what field there is for an expert engineer. An expert in engineering is something like a physician. The human system is subject to all sorts of ailments which the victim knows nothing about and which require the assistance of the doctor to alleviate or remedy. Much the same, the steam boiler, the engine, or the machinery of a factory suffers with disorders which require the assistance of someone who knows more about such things than the men who have them under daily care, or the owner himself, and recourse must be had to the steam or power doctor to put them to rights. More coal may be used than the owner thinks is needed. Unless the plant is tested analytically to find out the economy of the different organs and the manner and conditions under which they work, there is no certain means of determining the cause of the trouble, if any exists. Here is one very wide field for the work of the expert engineer, and one which Mr. Barrus has filled in a great number of steam plants.

All sorts of questions arise in the design and operation of a steam plant which are out of the ordinary, and need expert advice. There are guarantees in regard to the economy or capacity of engines, boilers and other appliances, the fulfillment of which must be determined by the disinterested expert before a final payment is made on a contract. There is power

or steam sold to a tenant, and disputes as to its quantity must be referred to and settled by the power expert. The investor in new interprises needs the services of someone to tell him the truth about the rival claims of competitors who are trying to sell him engines or boilers and the mass of appliances that are offered to him for a so-called up-to-date plant, and no one can do this better than the steam and power expert, who, from his wide experience, is likely to know the ills to which these things are subject. Assistance is required also in laying out the plant and in preparing specifications for bidders, and for this as well the expert engineer's services are needed. There are, too, suits at law in cases involving steam machinery, which few lawyers are competent to handle satisfactorily for a client, unless in close touch with a consulting engineer while the case is on trial.

It will thus be readily seen that the field is a broad one, and few men in this country have had a wider experience in these various classes of work in the past twenty-five years than Mr. Barrus. An important patent suit about five years ago developed the fact that, with the help of assistants, Mr. Barrus had personally conducted about 650 evaporative tests of boilers, 275 feed-water tests of engines, 100 complete tests of steam plants, 800 power tests, 250 calorimeter tests of coal, 600 tests of miscellaneous character, and had taken over 25,000 indicator diagrams. During the past five years the number has, of course, increased.

Mr. Barrus' early investigations led to the design of a "Superheating Steam Calorimeter" which acted on the entirely new principle of determining the moisture by direct measurement, rather than by the old total-heat apparatus of barrel calorimeters and the like, which give the results by the indirect and inaccurate method of differences. The new device was quickly appreciated by other engineers who immediately turned their attention to the superheating principle, and it resulted in the calorimeter which works on the principle of superheating by wire-drawing, largely used to-day. A student at Massachusetts Institute of Technology is believed to have been the first to suggest this idea for a calorimeter, but Mr. Barrus was the first to apply it in a practicable and satisfactory manner. His "Universal Calorimeter, 1895 pattern," is one of the most complete and serviceable applications of the wire-drawing principle that has been brought out; many of these instruments are in regular use by colleges and engineers, both in this country and abroad.

Mr. Barrus' work on boilers and coal economy early revealed the necessity of having, himself, some definite means of gauging the quality or calorific value of the fuel in any individual case when the character of the coal was uncertain. He tried that form of Thompson calorimeter which works by the principle of chemical mixture, but found this extremely unsatisfactory. Then he turned to the other Thompson instrument which burns the coal in an atmosphere of oxygen, and eventually worked out a device in this line which answered every purpose he had in view, and which he has used in his professional work ever since. Mr. Barrus found that the proper use of a calorimeter depends much upon the manipulation of the instrument, and it is seldom, therefore, that he delegates this kind of work to an assistant. He makes calorific tests for coal dealers, prospectors and others, in addition to those demanded by his own work, and has obtained a reputation in this kind of coal testing.

Mr. Barrus found on some of his first boiler tests that it was almost imperative to have some reliable means of measuring chimney draught, and especially small amounts of draught. The familiar U-tube lacked sensitiveness, and was difficult to read without great care. He made a rough device for multiplying the ordinary indication of the U-tube, by using multiplying chambers at the top of the two legs, and two different coloured li-

quids, so that for a 1-inch draught he obtained 8 inches motion on the scale, and for as light a draught as $\frac{1}{8}$-inch, a full movement of 1 inch. This improvement was in every way satisfactory, and the resulting instrument is one which he has since employed in all his boiler testing. For many years the instrument was made of glass throughout; but he has lately brought out one having only one side of glass, and this a removable straight glass tube, the remainder being made of metal.

Mr. Barrus has received, in no small degree, the honors which come to men of mark. He served on three occasions as a judge of the power exhibits at three of the triennial fairs of the Massachusetts Charitable Mechanics' Association held at Boston, being on each occasion chairman of the committee. In 1884 he was one of the Board of Examiners at the Electrical Exhibition at Philadelphia, given by the Franklin Institute. In 1893 he served as the Massachusetts member of the Board of Judges on Steam Power at the World's Columbian Exposition at Chicago. In connection with this work he was appointed by his associates as the expert to conduct a comprehensive series of tests on the engines and boilers exhibited at the fair, which were proposed, although never carried out.

Mr. Barrus joined the American Society of Mechanical Engineers in 1883, and since that time has contributed many papers and discussions to its transactions. He was chairman of the committee of the society which prepared a "Standard Method of Conducting Duty Trials of Pumping Engines," the other members of that committee being Edwin Reynolds, J. J. de Kinder, A. F. Nagle and J. S. Coon. He also served on a similar committee of the society for devising standard trials of locomotives, and one for standard tests of engines in general.

He was also a member of the Revision Committee on the "Code of Rules for Conducting Boiler Trials," the other members being Messrs. Emery, Porter, Thurston, Kent, Dean, Hunt, Coon and Potter. He is a member of the Boston Society of Civil Engineers, the New England Water Works Association, the Society of Naval Architects and Marine Engineers, and belongs to the Engineers' Club, the Technology Club, the Boston Club and the Allston Golf Club.

He is the author of books entitled "Boiler Tests" and "Engine Tests," as already stated; also of one on the "Tabor Steam Engine Indicator," and one on "The Star Improved Indicator;" and has contributed many papers and articles to societies of which he is a member, and to mechanical engineering journals. He uses clear and concise language, and his treatment of a subject is marked by breadth of view, independence and logical presentation, which win the confidence of the reader. He is fearless in the criticism of erroneous views, and zealous in upholding what he considers right.

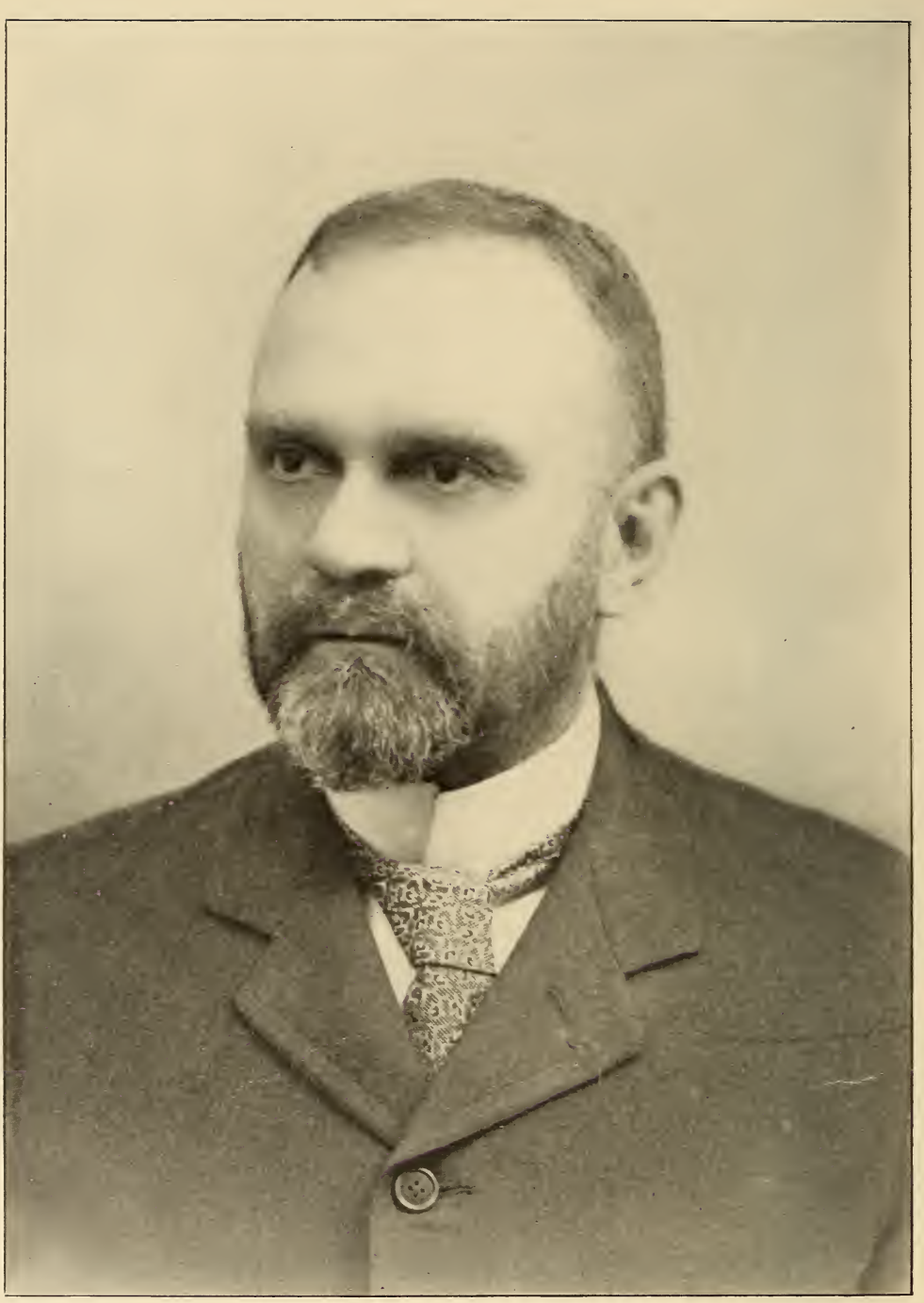


PHOTO BY LINTOTT, LONDON

AXEL SAHLIN

SEE PAGE 248

INDEXED

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ELECTRIC POWER DEVELOPMENTS IN MEXICO

By Francis O. Blackwell

THE conditions in Mexico are peculiarly favourable for the hydro-electric development of power, as fuel for the generation of power from steam is expensive. The supply of wood in the settled portions of the country is now nearly exhausted, and coal at ports on the Gulf of Mexico costs about $6.00 gold a ton, while in the interior the cost of transportation increases the price per ton from $10 to $20. The country is mountainous, and, though no large rivers exist, high waterfalls make many developments possible.

In common with all tropical countries, Mexico has a wet and a dry season, and the flow of the streams is extremely variable. In general, in order to obtain a reliable power of large proportions, it is necessary to construct storage reservoirs to conserve the flood waters of the rivers for the dry season. The value of a Mexican water power generally depends very largely on the possibilities of obtaining storage for this purpose.

The industries of Mexico are varied and are growing rapidly. Agriculture and mining have been, in the past, the chief sources of the wealth of the country, but, under the liberal and patriotic administration of President Diaz, manufactures of all kinds have sprung up and their number is constantly increasing. In addition, many of the old mines, long thought to have been worked out by the Spaniards, have been reopened and successfully worked on a large scale with modern methods and improved processes for reducing the ore.

Cheap power also makes it possible to economically mine from greater depths, to cope with large quantities of water and to successfully handle ores of lower grade than those worked a few years ago. Many new mining districts are being discovered which can profitably be worked only on a large scale by water power. The country is already being benefited by the utilization of some of its water powers, but the field is such a large one that the work has only just begun.

The first water power electrically developed in Mexico was at the Falls of Juanacatalan in 1901. At that time this plant was the largest of its kind, it used the highest potential, and from it power was transmitted for a longer distance than in any other in-

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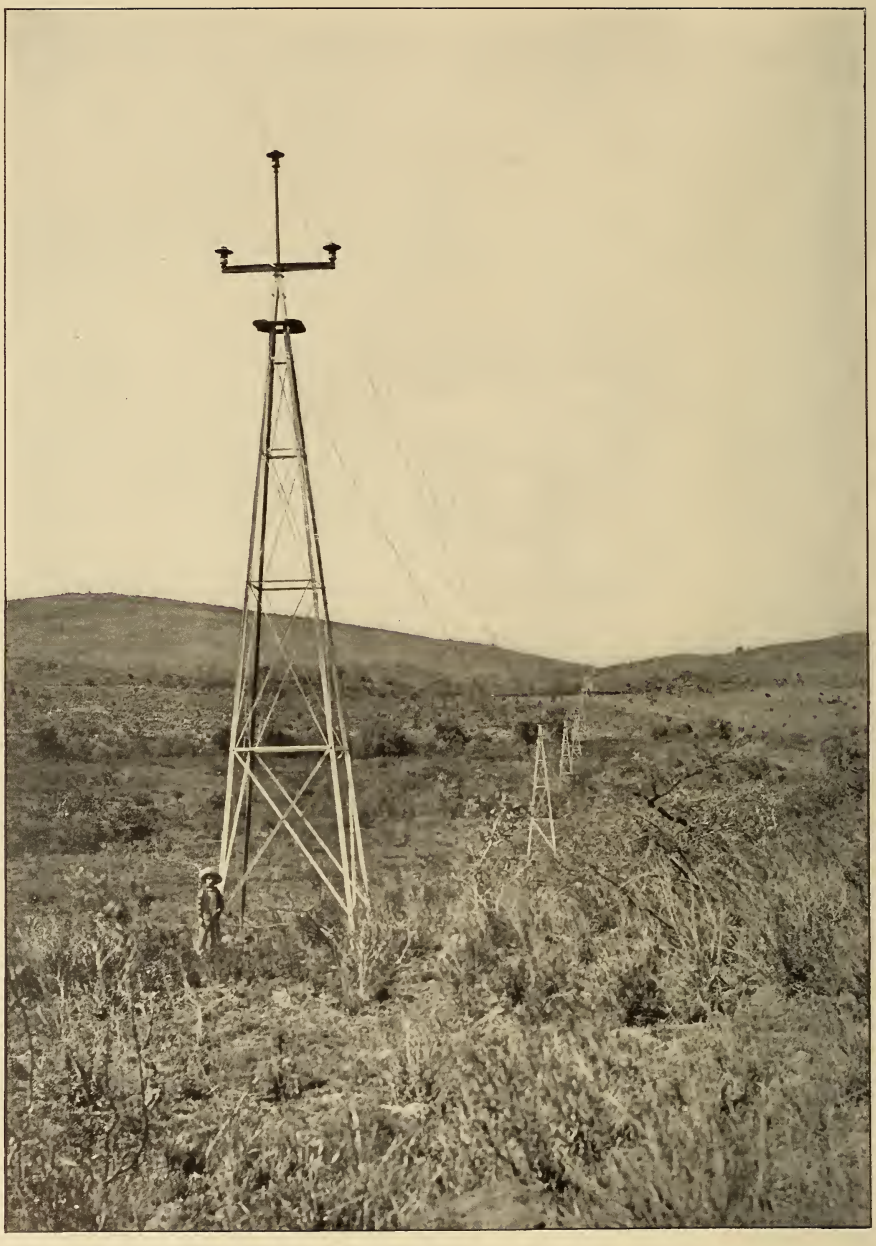


ALONG THE TOWER LINE OF THE GUANAJUATO POWER & ELECTRIC COMPANY. THE TOWERS WERE BUILT BY THE AERMOTOR CO., OF CHICAGO, ILL.

stallation in the world. At Juanacatalan the Lerma River has a fall of fifty feet. By installing turbines belted to two 300-KW single-phase alternators, with a periodicity of 100 cycles per second, power was generated and transmitted over an iron-pipe pole line to the city of Guadalajara—a distance of seventeen miles—where it was used principally for

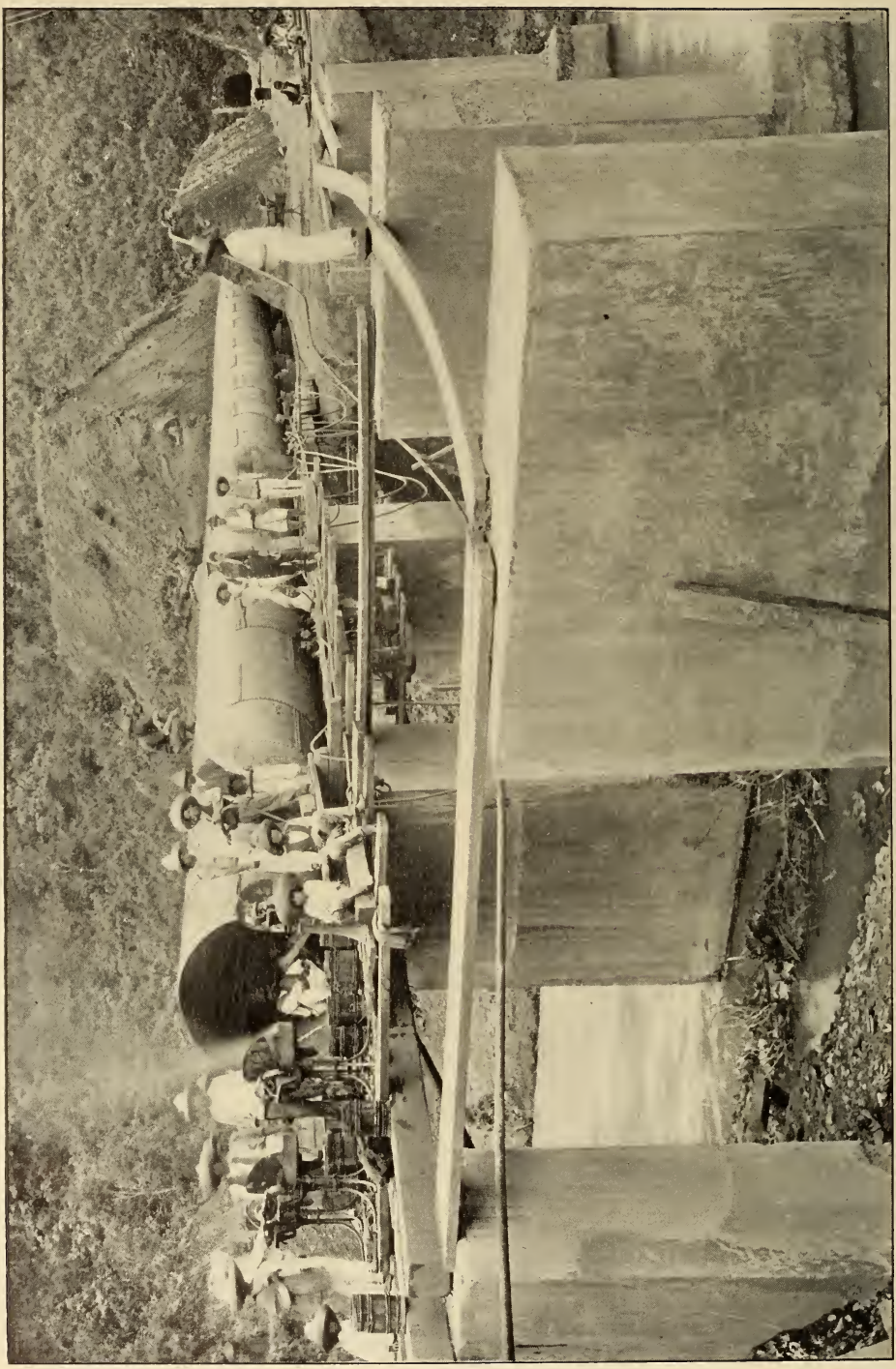
lighting. The transmission potential was 5000 volts,—extraordinarily high for that day. This plant was successful and has since been much enlarged. By building a dam across the outlet of Lake Chapala—the largest lake in Mexico—the minimum flow of the river was subsequently considerably increased and the plant made much more reliable.

The next step in the progress of hydraulic construction was at Regla, where a high-head water-power plant with multiphase apparatus was constructed along modern lines in 1895. By building a canal, 11½ miles long, with eleven tunnels, in the Barranca of Regla, an effective head of 800 feet was obtained. This was carried to the power house by 2200 feet of 30-inch pipe. Five impulse water wheels, each of 400 H. P., and running at 600 revolutions per minute, were installed in the power house and di-

THE BARRANCA OF REGLA. THE CANAL AND TUNNELS FOR THE PACHUCA POWER PLANT ARE IN THE FOREGROUND UNDER THE BASALTIC COLUMNS, THOUGH NOT READILY DISCERNIBLE IN THE ILLUSTRATION

THE FIRST NECAXA FALLS, SHOWING THE ENGINEERS' CAMP ABOVE AND THE CONSTRUCTION PLANT BELOW

THE SECOND NECAXA FALLS, 740 FEET HIGH. A CAGE FOR LOWERING MACHINERY TO THE POWER HOUSE IS SHOWN IN THE UPPER LEFT-HAND CORNER



THE 6-FOOT FEEDERS BETWEEN THE TUNNELS OF THE NECAXA PLANT, IN PROCESS OF CONSTRUCTION

TENANGO FALLS, WHICH PLAYED AN IMPORTANT PART IN THE NECAXA DEVELOPMENT

rectly connected to an equal number of 300-KW three-phase alternators. The current obtained from the generators at 700 volts was stepped up to 10,000 volts and transmitted over a steel pole line seventeen miles to Pachuca. The power was used in Pachuca principally for operating the mines of the Rio del Monte Company and the mills and reduction works in the city.

The next important advance in power transmission was made in the plant of the Guanajuato Power & Electric Company, which has been in operation since 1903. This company constructed a power plant near Zamora, where, by excavating five miles of canal and laying 3300 feet of pipe, a head of 320 feet was obtained. Two units are installed, each consisting of two 1125-H. P. impulse wheels and a 1250-KW, 60-cycle, three-phase generator running at 200 revolutions per minute. The current from these machines is raised to 60,000 volts by three 1080-KW oil transformers and transmitted 110 miles over a single circuit to the city of Guanajuato, where the power is used in the silver mines and mills. The capacity of this plant is now being doubled

THE VALLEY ABOVE SALTO CHICO, SHOWING THE NECAXA PIPE LINES AND TUNNELS

by the addition to it of 5000 H. P. This transmission is notable for its length and because it is the first in which an all-metal line construction, long spans and a potential of 60,000 volts were used. The towers are of galvanized steel with 3-inch x 3-inch x 3-16-inch corner angles, 8 feet apart. The spans are of 440 feet, and occasionally longer, up to 1500 feet. The conductor is a 19-strand copper cable equivalent in cross section to a No. 1 B. & S. wire. The cable is supported by 14-inch, 3-part porcelain insulators, and cast-iron pins at heights of 41 and 47 feet from the ground, with a sag in the conductor of 10 feet. A telephone line is carried by the same towers and keeps the two ends of the plant in constant communication.

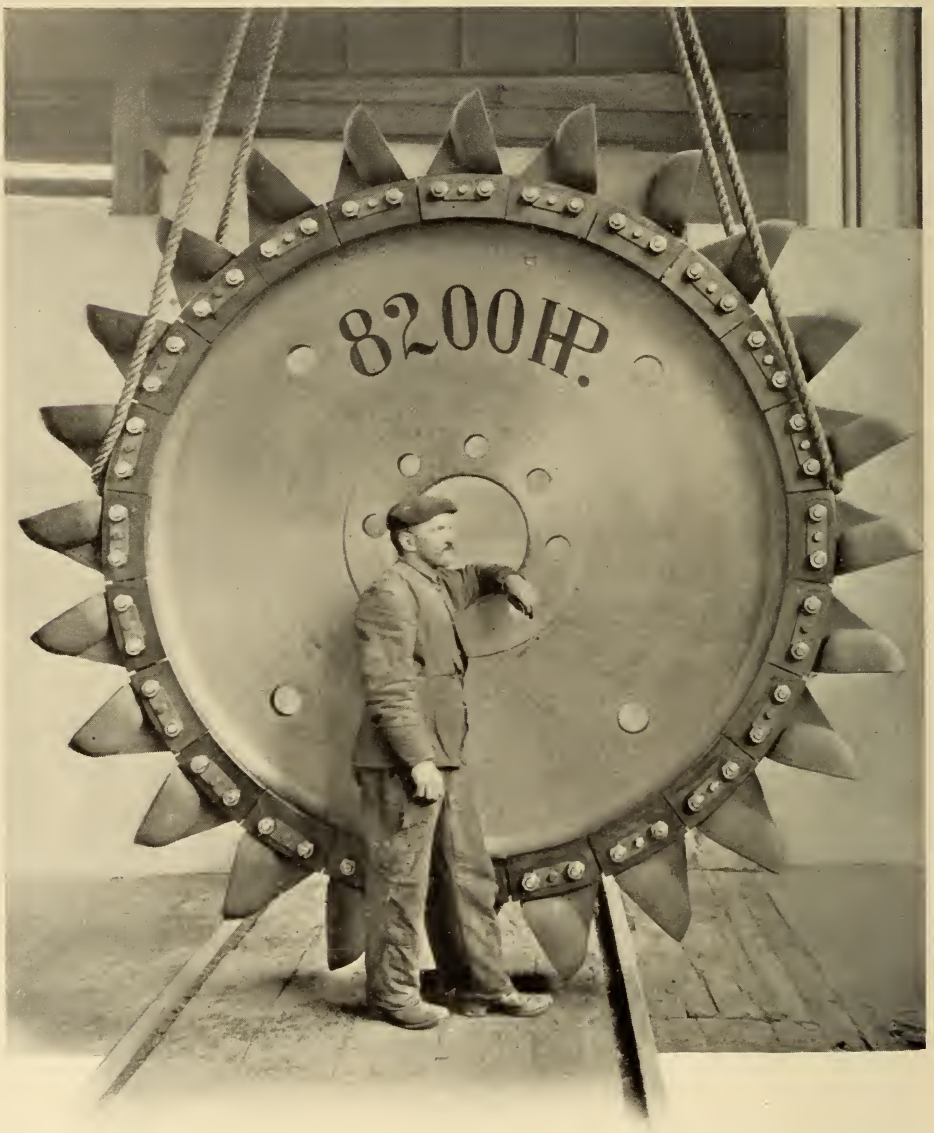
In tropical countries the use of wooden poles is objectionable on account of their short life. In Mexico the cost is also excessive as they must be imported from the United States. The substitution of steel not only reduces the first cost but also gives a strong, permanent and fireproof construction, making the line much less liable to interruptions. The towers are also conveniently handled in a mountainous country, as they can be knocked down and packed in bundles for mule-back transportation and assembled at the points where they are to be erected. With long spans the less number of insulators is also an advantage, in that it permits a larger and safer insulator and higher potentials to be employed than is possible with short spans.

The latest plant now under construction is that of the Mexican Light & Power Company at Necaxa. It will be one of the largest power plants in the world, and, in addition, will deliver power over a greater distance than has yet been undertaken by any other installation. The Tenango and Necaxa Rivers drain a portion of the central plateau on which the City of Mexico is situated, and, at a point about 100 miles northeast of the City, pass through the mountains at an elevation of 4300 feet above sea level. A few miles below the town of Necaxa the Tenango River flows into the Necaxa River and eventually discharges into the Gulf of Mexico about sixty miles farther East.

There exists on both rivers a remarkable series of waterfalls with a total drop of about 3000 feet in 3 miles. The rivers have a combined drainage area of 227 square miles upon which the rainfall varies from 85 to 135 inches per year, most of it being concentrated in the rainy season from May to December. The combined flow of the streams is, as might be expected, extremely variable, the minimum recorded flow being one cubic metre a second and the maximum 90 cubic metres. The average flow during the year of lowest recorded rainfalls was about 7 cubic metres per second.

The plan of development decided upon was to turn the Tenango River into the Necaxa by means of a diverting dam, 16½ feet high and 280 feet long, and a tunnel 11 x 7 feet in cross section and 3000 feet long. A favourable location for a large storage reservoir exists at Necaxa, making it possible to equalize the entire flow of the streams during a dry year. A short distance below the site for the reservoir there are two falls in the Necaxa River, one 300 and the other 750 feet in height, which, together with the rapids above and between them, give a total fall of 1300 feet in a mile. The initial plant will utilize this head, but there is a further fall immediately below of 1300 feet which will be developed as soon as the first plant is completed. The two plants will eventually be capable of furnishing 80,000 electric horsepower.

The ground at the site of the dam is an unreliable volcanic rock, and, as no rigid bottom exists upon which to build masonry, an earth dam has been decided upon. This dam will be 177 feet high and 600 feet long at the crest, with a width at the base of



ONE OF THE 8200-H. P. WATER WHEELS BUILT FOR THE MEXICAN LIGHT & POWER COMPANY BY ESCHER, WYSS & CO., ZURICH, SWITZERLAND.—SEE PAGE 182

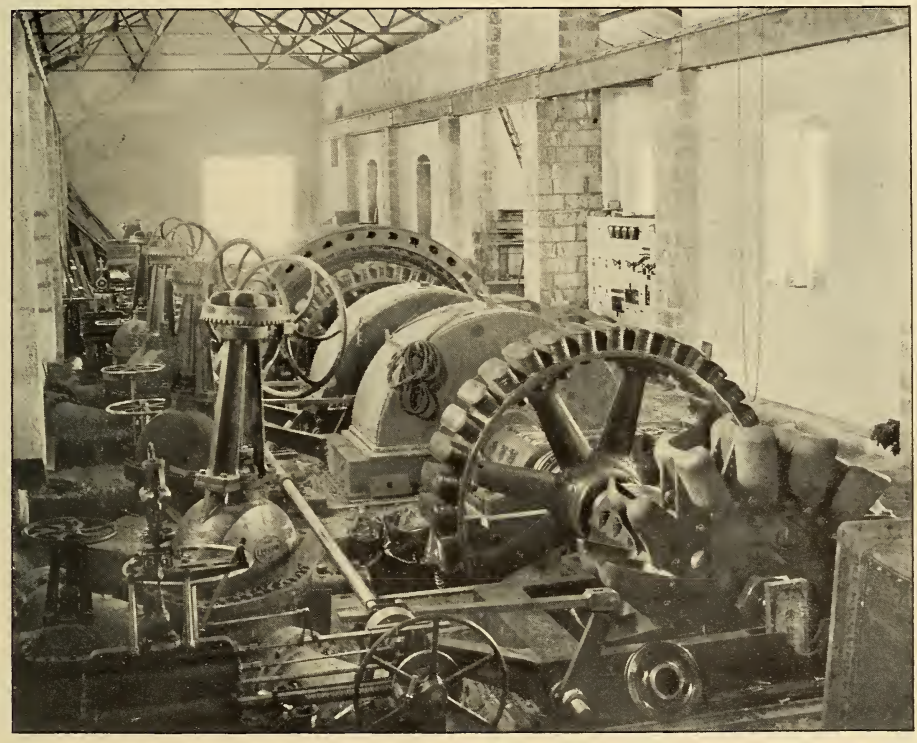
950 feet, and at the top of 54 feet. The slopes will be 3 in 1 on the up stream and 2 in 1 on the down stream faces. About 2,000,000 cubic yards of material will be required in its construction, and will be obtained from the neighbouring hills and sluiced into place by the methods that have been so successfully used in many hydraulic fill dams in the Western part of the United States under similar conditions.

The hydraulic system originated in the placer mines of California and is the most rapid and economical method of excavating and transporting large quantities of earth and rock wherever a sufficient volume and head of

water are available, as at Necaxa. The method employed is to first loosen the earth by blasts and then wash the material into flumes which carry it to the site of the dam. A low embankment is first made at the upper and lower sides of the fill and drainage culverts are provided to the centre. The flumes discharge their contents near these embankments, the coarse stone and gravel settling there, while the finer materials are deposited near the centre, forming an impervious core wall. As an additional protection, the inner and outer slopes of the dam are protected by a layer of broken stone from 8 to 60 feet thick. The spillway is cut out of the hill to the north and discharges the overflow well down stream where it cannot endanger the work.

The reservoir formed by this dam, when full, will cover an area of three square miles and have a storage capacity of 1,580,000,000 cubic feet. The outlet from the reservoir will be through a tunnel 1550 feet long, driven in the rock to the south of the dam. Water is admitted through screens to two vertical pipes embedded in concrete, each pipe having gates at four different levels, so that the gates will not have to be operated under pressure.

The vertical pipes are joined to horizontal penstocks, 8 feet in diameter and $\frac{3}{8}$-inch thick, which pass through the tunnel, the latter being subsequently filled with masonry. The penstocks, after they leave the tunnel, are reduced to a diameter of 7 feet and are carried down stream a distance of 2800 feet, 900 feet of which are through tunnels. At this



IN THE POWER HOUSE OF THE GUANAJUATO POWER & ELECTRIC COMPANY, NEAR ZAMORA. GENERAL ELECTRIC GENERATORS AND WATER WHEELS MADE BY THE PELTON WATER WHEEL CO., SAN FRANCISCO

point, under a head of 180 feet, the penstocks are joined to a receiver, 22 feet long and 7 feet in diameter, from which six smaller pipes conduct the water to the power house. All pipes are connected to the receiver through gate valves, and, in addition, a valve in the center of the receiver permits the two halves of the system to be separated from each other, so that either half can be shut down without interfering with the other.

The pipes from the receiver are carried down to the power house, a distance of 2300 feet, 1900 feet of which are through two parallel tunnels constructed at an angle of 41 degrees from the horizontal. There are three pipes in each tunnel supported on concrete with anchorages and expansion joints. These pipes are seamless steel tubes with flanges, each piece being forged complete from one piece of sheet steel. Before the flanges are hammered out, two cast-steel clamping rings are slipped on each 30-foot section of pipe. The outside diameter of the tubes is $30\frac{5}{8}$ inches throughout the entire length of the line. The internal diameter of the tubes is less at the lower end than at the upper on account of the pipe's greater thickness, which varies from 0.4 to 0.95 of an inch, the minimum diameter being 29 inches.

The static head at the lower end of the 30-inch pipe, with the reservoir full, is 1430 feet, which is reduced to 1300 feet when the reservoir is empty and the friction loss is allowed for. A vertical relief pipe, 240 feet high and 20 inches in diameter, is connected to the upper end of each penstock. Each section of tube before being shipped from the works of the manufacturer in Germany, was subjected to a hydrostatic test of twice the maximum pressure to which it will be subjected in service. This pipe is stronger and more reliable than one built up of plates and flanges riveted together, such as is commonly used, and the smooth interior will materially reduce the loss of head due to friction.

The power house is located in the Necaxa canyon a short distance below the 750-foot waterfall. It will have a rated output of 30,000 KW, or 40,000 H. P., and a maximum capacity of 50,000 H. P. There will be six main water-wheel units, each capable of delivering 8200 H. P. They are of the impulse type built by Escher, Wyss & Cie, of Zurich, Switzerland, and are of 100 inches pitch diameter, running at 300 revolutions per minute. Each has two $4\frac{1}{2}$-inch square regulating nozzles fixed on opposite sides of the wheel, but joined together so that they are opened and closed simultaneously.

A by-pass valve is provided at the end of the pipe line which feeds each unit and is mechanically connected to the nozzles, so that when one opens the other closes, keeping the flow of water in the pipe constant. This is necessary to avoid rams which might prove disastrous with such a high head and long penstock.

A vertical shaft, 14 inches in diameter, carries both the field of the generator and the water wheel. The weight is supported by a thrust bearing, 30 inches in diameter, under which oil is forced at a pressure of 150 pounds per square inch by a pump driven by the main water wheel. This construction has many marked advantages over impulse water wheels heretofore built with a horizontal shaft and a single deflecting nozzle. The double nozzle reduces the size of both the jet and the bucket, and permits the use of a smaller diameter of water wheel and a higher speed of rotation without sacrifice of efficiency. The nozzle and by-pass are much more easily operated and possess the other good features of a deflecting nozzle. As the nozzles are set in opposition to each other there is no thrust on the steady bearings, and no weight is carried by the latter, so that they need be only a fraction of the size required for a horizontal shaft. The diameter and length of the shaft itself can also be much reduced. The oil thrust bear-

ing is a very simple and reliable device which operates with a minimum of attention.

The amount of water supplied to each wheel and the maximum power can be adjusted at the governor so that water will not be wasted unnecessarily, and the by-pass is also arranged so that, if desired, it can be adjusted to close slowly after opening,—a feature which may be desirable with fairly steady loads.

Each unit is equipped with a 28-inch diameter gate valve and a governor of the Escher-Wyss type, both operated by hydraulic power. The six 5000-KW alternators direct connected to the water wheels, running at 300 revolutions per minute were furnished by the Siemens-Schuckert Werke, of Berlin. They are of the revolving field type and generate three-phase current at a periodicity of 50 cycles, and a potential of 4000 volts. Two of the alternators are equipped with 60-KW, directed-connected, 125-volt exciters, but in ordinary operation exciting current will be obtained from two 250-KW, 125-volt generators driven by induction motors wound for 4000 volts. Motor-generator sets are employed, because with small wheels the small nozzles are constantly stopped up by materials floating in the water.

The low-potential current from the generators is raised to high potential by five banks of oil transformers, each bank consisting of three 2000-KW units which can deliver power at 40,000, 50,000 or 60,000 volts to the transmission circuits. The transformers are each placed in a closed fireproof compartment, with steel bulkheads separating them from the generator room, on account of the large quantity of oil used to insulate them. The heat generated, due to the losses in the iron and copper, is carried away by copper cooling coils in the transformer cases, through which water is constantly circulated by motor-driven pumps.

The wiring consists either of cables in conduits or of bare wires in brick and concrete compartments, so that the damage from an arc is limited and cannot injure adjacent circuits. This is particularly important in laying out the 60,000-volt circuits, a substantial wall isolating every wire, switch or lightning arrester. The main switches are all of the oil type controlled electrically from a distance, and any switch will open instantaneously a short circuit of the entire power system. They are also equipped with disconnecting air switches so that they can be cut off from the system for repair and inspection. The high-tension wiring and the lightning arresters are all in a room by themselves behind the transformer pockets.

The oil switches are on the gallery above, with the controlling switchboard in the centre, where the operator can obtain an unobstructed view of the machinery in all parts of the building. The small controlling switches for the large oil switches are, with the miniature lamps which indicate their position, mounted on a benchboard with dummy bus-bars to form a wiring diagram so that the attendant can always see how the apparatus is connected and thus avoid mistakes.

On vertical panels above the benchboard are the indicating instruments which show at any instant the speed, potential and power at which the plant is operating. These instruments are also so placed with relation to the dummy busses and operating switches that the operator cannot become confused. At the back of the board are the registering instruments which make a record of the pressure and output of the plant. The switchboard forms a room, with the instruments and controlling devices on the outside, and doors at the ends to give access to the inside. The transformers and switchboard were furnished by the General Electric Company, of Schenectady, N. Y.

The power house is a substantial steel and masonry building, with concrete and cement roofs, floors and

ROLLING STOCK OF THE MEXICAN LIGHT & POWER CO. THE LOCOMOTIVES ARE FROM THE WORKS OF THE H. K. PORTER CO., OF PITTSBURGH, AND THE LIMA MACHINE WORKS, OF LIMA, OHIO, U. S. A.

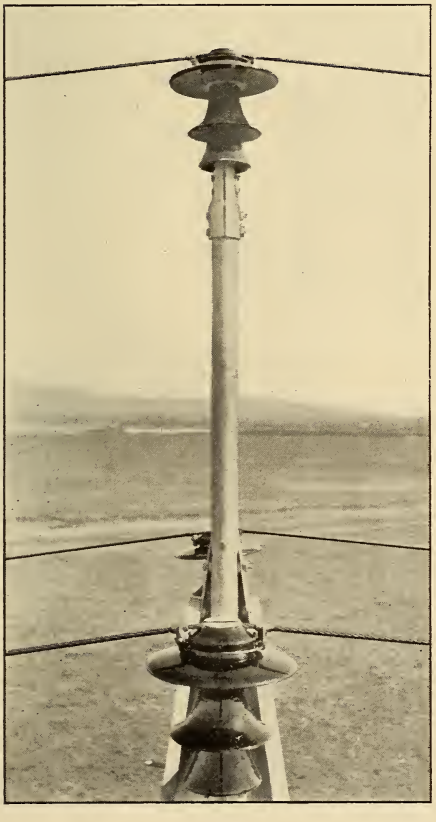
partitions, in which no combustible material of any kind is employed. All the machinery is placed where it can be readily handled by a 50-ton travelling crane. At one end are storerooms for supply and repair parts, and a machine shop equipped with all tools necessary to maintain the apparatus. The building is 235 feet long, 88 feet wide and 60 feet high.

The Necaxa plant is located in one of the most inaccessible parts of the State of Puebla, and for its construction it was necessary to build 30 miles of railroad, besides many miles of roads and trails. The material and machinery for the power house had to be lowered down cliffs and steep inclines by cableways for a vertical distance of 1500 feet, and nearly all the apparatus had to be transported over 4000 miles from Europe and the United States. A temporary plant, consisting of two Pelton water wheels driving air compressors and a 500-volt continuous current generator for operating the hoisting, pumping and other construction machinery, and lighting the work at night, was installed beneath the first fall at Necaxa.

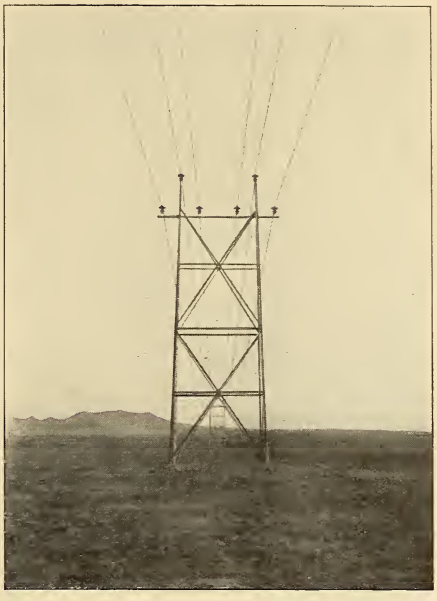
There are four electric power transmission circuits and two tower lines from the power house to the City of Mexico, and two circuits from the City of Mexico to El Oro. They are carried by steel towers, on each of which are two circuits of 168,000-circular mils copper cable, equivalent to No. 000 B. &. S. wire, supported on 14-inch diameter porcelain insulators. The towers for the transmission line are built up of steel angles with all parts heavily galvanized and with 3-inch x 3¼-inch corner posts spaced 16 feet apart across the line and 12 feet along the line. They are 50 feet high over all, the feet being set 5 feet in the ground. The six cables are supported 40 and 46 feet above the ground, the conductors forming two equilateral triangles with 6-foot sides. The towers will stand a horizontal side strain of 1650 pounds

at each insulator pin, or 10,000 pounds altogether. The standard distance between them is 500 feet, but spans up to 1200 feet are made by allowing additional sag and employing special structures.

The insulators are made in three parts cemented together on the ground in Mexico. Each part is tested before shipment by subjecting them while wet to a test potential of 60,000 volts. After being assembled they are tested with a potential of 120,000 volts. The insulator pins are 15 inches long and made of 2-inch steel pipe set in drop-forged sockets, which in turn are mounted on a 4-inch pipe cross-arm for the lower conductors, and a 3-inch pipe extension for the upper. They are set into the insulators with Portland cement.



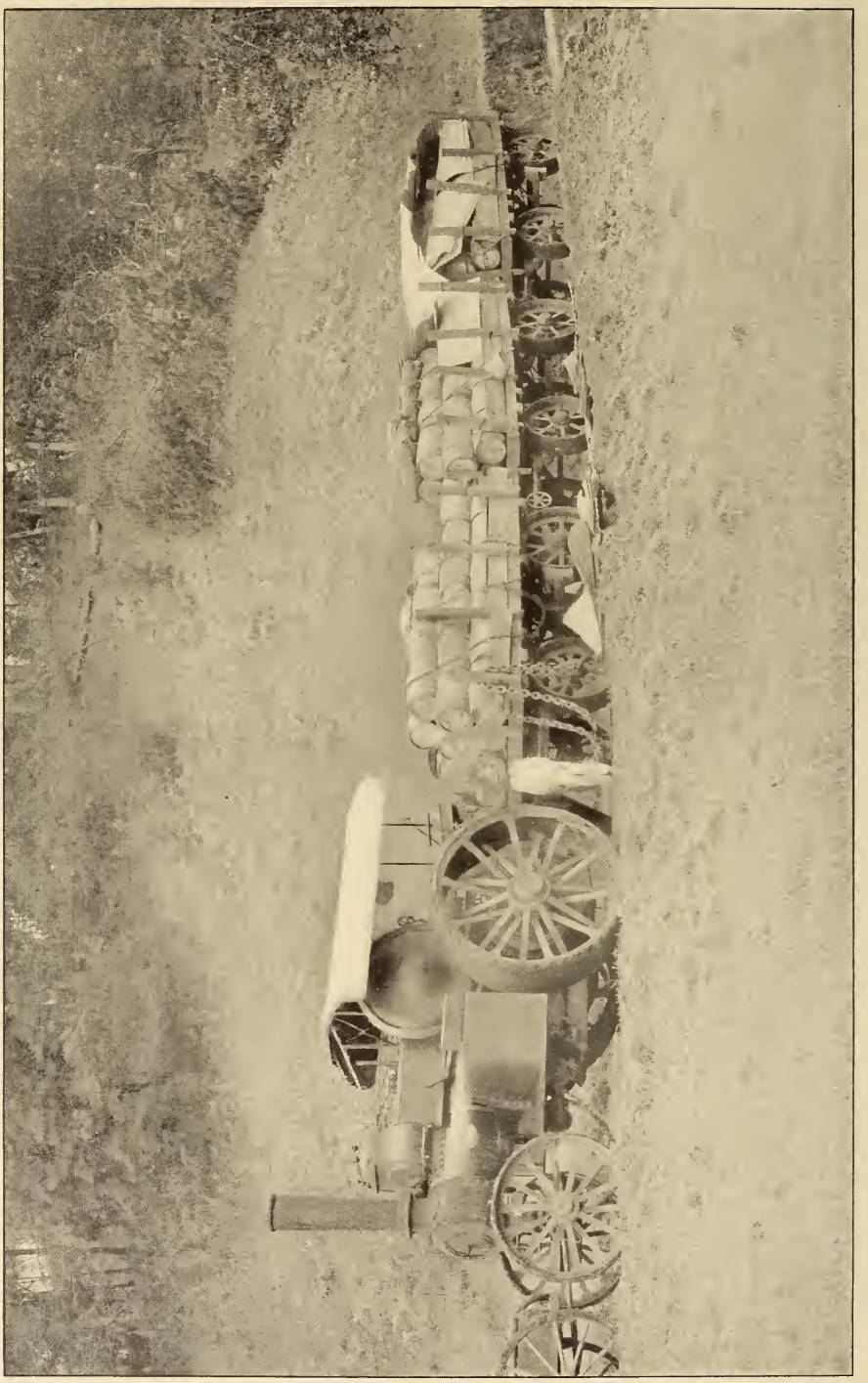
INSULATORS USED BY THE MEXICAN LIGHT & POWER CO., MADE BY THE R. THOMAS & SONS CO., EAST LIVERPOOL, OHIO



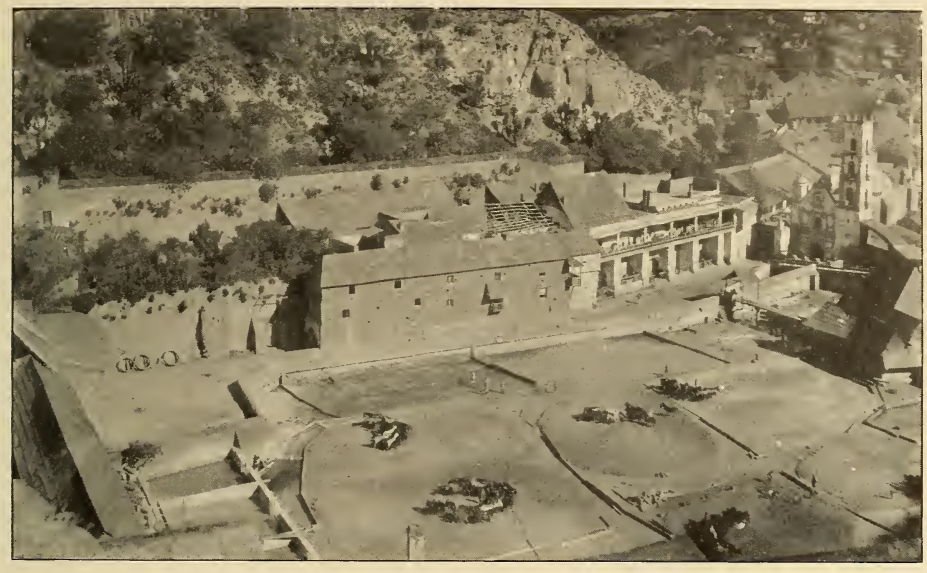
A TOWER ON THE LINE OF THE MEXICAN LIGHT & POWER CO., MADE BY THE RITER-CONLEY MFG. CO., PITTSBURGH, PA.

The conductors are six-strand copper cables, $\frac{1}{2}$-inch in diameter, with hemp centres, and have a strength of 60,000 pounds and an elastic limit of 40,000 pounds per square inch. The cable is shipped in lengths of 3000 feet, and joints are made with an 18-inch twisted copper sleeve. The stress on the cables and supporting structures is figured by assuming a wind velocity of 100 miles an hour and allowing a stress in the materials of one-half the elastic limit. The cables are attached to the insulators by clamps, no tie wires being employed. Telephone circuits of No. 10 copper wire are erected on each of the tower lines and are placed 10 feet below the high-potential cables.

The distance from Necaxa to Mexico is 96 miles, and from Mexico to El Oro 75 miles. The total length will therefore be 171 miles, making it the longest commercial power transmission yet constructed. There will be 1602 miles of cable and 534 miles of circuit in the high-potential sys-



HAULING A 30-TON LOAD OF CEMENT BY A JOHN FOWLER & CO., LTD., LEEDS, ENGLAND, TRACTION ENGINE TO THE SITE OF THE POWER HOUSE OF THE MEXICAN LIGHT & POWER COMPANY



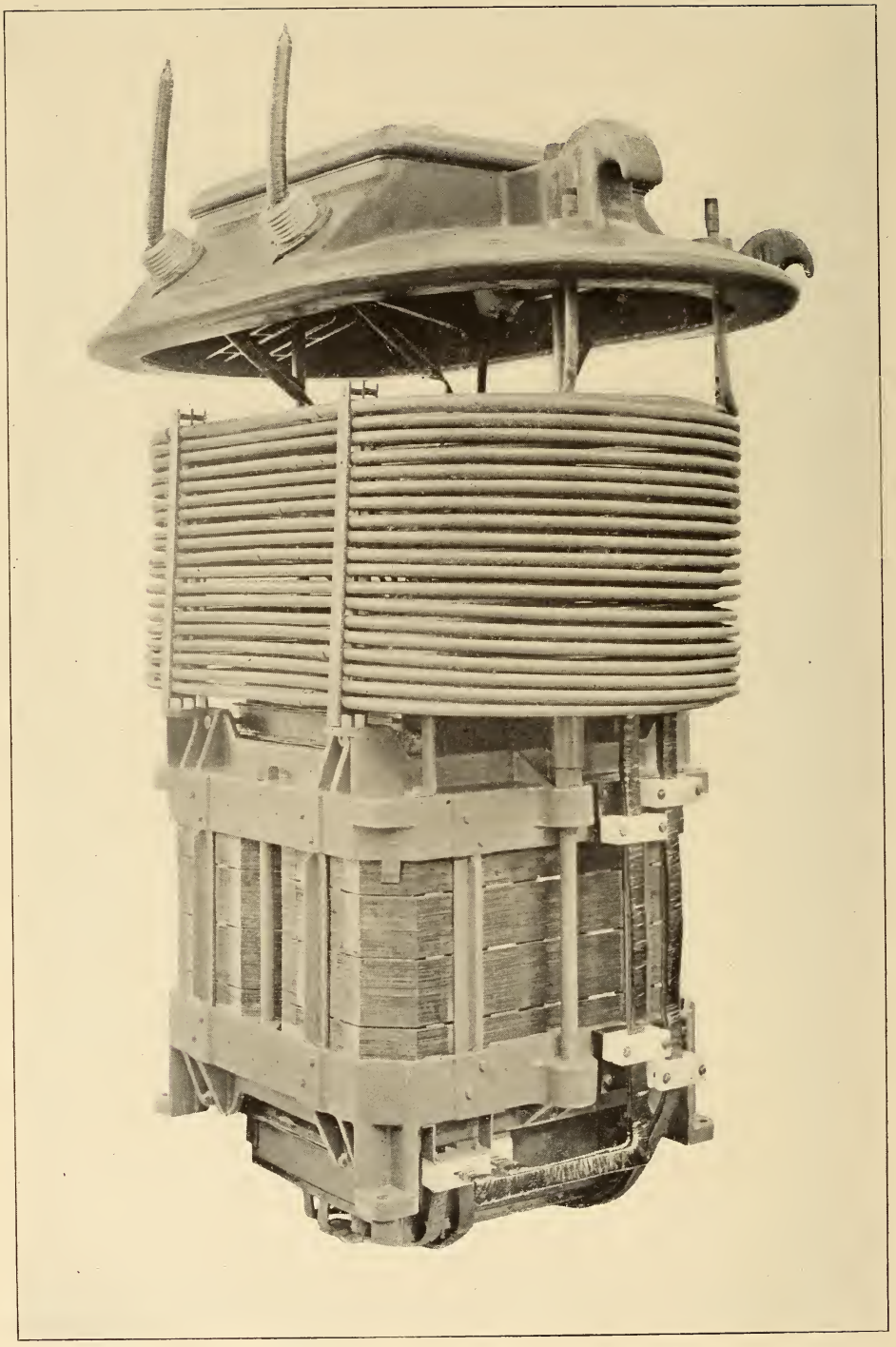
PATIO PROCESS IN THE HACIENDA DE BENEFICIO OF THE RIO DEL MONTE MINES, PACHUCA. ONE OF THE CONSUMERS OF NECAXA ELECTRIC POWER

tem. The loss in the transmission circuits between Necaxa and Mexico will be 8 per cent. at full load, with 100 per cent. power-factor at 60,000 volts, so that the entire power can be delivered over two of the four circuits, or one-half the transmission system, with only 16 per cent loss, should the other half be disabled. The loss in transmission from Mexico to El Oro is but 5 per cent.

The circuit breakers at Necaxa, Mexico and El Oro are arranged to automatically cut out any transmission circuit which becomes damaged without any interruption in the service. The sub-station buildings in the cities of Mexico and El Oro follow in general the design adopted for the power house. In Mexico there are twelve 1800-KW oil transformers in separate fireproof compartments covered by a travelling crane. The switches and wiring are in separate cells and every precaution has been taken to isolate all parts from each other. In addition to the high-tension apparatus, an extensive low-potential feeder system for the city distribution is provided for in the switchboard. The step-down transformers are arranged to furnish current at either 1500, 3000 or 6000 volts, as may be required.

The building is 203 feet long and 65 feet wide, and is located adjacent to the company's steam station, originally built by the Siemens-Halske Company. This steam plant now supplies the public lighting of the city and much private lighting and power. In it are installed six 1200-H. P., triple-expansion, condensing engines, running at 120 revolutions per minute, direct connected to 50-cycle, 1500-volt, three-phase alternators. Four 1000-H. P. Curtis steam turbines running at 1500 revolutions per minute are now being erected in advance of the completion of the water power installation to take care of the rapidly increasing business. Later, this station will be kept as a reserve, although it now seems probable that steam will be required even after the water-power plant is in operation, as practically all the power from the first Necaxa development has already been sold.

At El Oro, a sub-station, 115 feet



ONE OF THE 60,000-VOLT TRANSFORMERS BUILT FOR THE MEXICAN LIGHT & POWER COMPANY BY THE GENERAL ELECTRIC CO., OF SCHENECTADY, NEW YORK

long, and 59 feet wide has been erected. This is similar to the one in Mexico, and the seven 1800-KW step-down transformers installed there are duplicates of those in the latter city.

The distribution to the gold mines of the El Oro and Tlalpujuhua districts will be at 3000 and 6000 volts. The mines at Tlalpujuhua were first worked three hundred years ago by the Spaniards, who are credited by tradition with having taken enormous quantities of silver from them. That gold existed in the neighbouring town of El Oro was known for a century, but it was not until comparatively recently that the cyanide process made it possible to recover the metal from the ores. The great success of the El Oro Mining & Railway, the Esperanza and the Dos Estrellas Companies, has brought the camp into prominence, and many other properties are now being actively developed. Enormous bodies of ore, the veins in places being 200 feet thick, have already been opened up over a wide extent of territory, and El Oro promises to rival, if it does not surpass, the Rand in South Africa, as the world's greatest producer of gold. The mines must, however, be worked on a large scale to be profitable, and the introduction of cheap power has greatly stimulated the activities of the whole region.

SWITCHBOARD IN THE POWER HOUSE OF THE MEXICAN LIGHT AND POWER CO., MADE BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

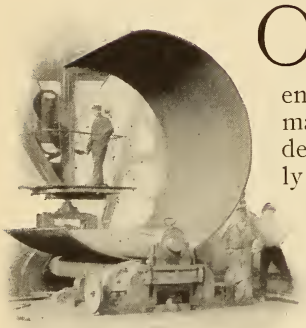
The Necaxa plant has been designed with ample reserve power so that the failure of no single piece of apparatus or combination of accidents ever will be likely to cripple the plant. The pipe lines will be in duplicate, reserve units of each kind of

hydraulic and electric machinery will be installed, and the transmission lines will have double and quadruple circuits. The buildings, transmission towers and other structures are of permanent and reliable character.

Mexico is generally admitted to be the best lighted city on the American Continent, and it is expected that the same high standard of service will be maintained after water power has replaced steam.

THE DEPRECIATION PROBLEM

By John L. Bronson



ONE of the most difficult subjects with which the engineer as a business man has to deal is the depreciation physically of the plant with which he is connected. The problem presses with special force upon the electrical engineer, associated as he is with apparatus rapidly undergoing improvement with the advance of applied science; but it also faces the mechanical engineer in the study of every plant and machine; and it cannot be neglected in the static structures of any branch of civil engineering. Depreciation is a property of everything created by human hands, and it should not be overlooked in any intelligent analysis of industrial activity.

Two important obstacles exist in the way of making proper depreciation allowances in operating a commercial plant. The first is the attitude of many boards of directors upon the subject, and the second is the lack of knowledge existing as to a correct allowance for the particular property under consideration. Within the past decade or two the necessity of providing reserve funds in excess of those paying the cost of ordinary wear and tear has begun to be more generally recognized, particularly in those industries which have become classed as long-established. In the later fields of activity, among which street railway work may be cited as a prominent example, there is still room for an enlarged conception of the importance of depreciation. In all the range of engineering practice, it would be hard to find a better example of the depreciation caused by the advance of applied science than that presented in the evolution of the telephone switchboard, which has been improved so rapidly within the past seven or eight years that vast sums have been expended in equipment which is now as obsolete as though it had been dug out of the ruins of Pompeii.

In cases where the importance of providing for depreciation and sinking funds is not appreciated, the manager of the property is in duty bound to explain to his directors, if they lack the knowledge, that the bonds of the company should be looked upon as a debt which must ultimately be extinguished, if the stock is to retain its value. The payment of bond interest does not reduce this debt. Furthermore, if the security of the bondholders is to be maintained, a sum adequate to provide for the depreciation of the property so that all necessary repairs and renewals can be made, must annually be set aside. It is often a difficult matter to press these points home in the face of the

desire to declare as large dividends as the income will bear, and to approach the subject more intelligently it is most important that accurate figures upon the life of equipment in the property and in others operating under generally similar representative conditions, be available, together with succinct statements as to the cost of maintenance.

It is difficult to determine at the present time what to allow for depreciation in industrial plants and systems. Some companies attempt to cover the case by setting aside a definite percentage of net earnings, which is supposed to represent the average decrease in value of the property under the conditions of operation. Others are trying to classify the main divisions of equipment and to determine the depreciation percentage separately with reference to the life of the various elements. There is no objection to the first method if the percentage is not placed absurdly low or unreasonably high, but unless some estimate of wear and tear, not replaced in the ordinary work of maintenance, is made along the lines of the second method, the results are likely to be considerably wide of the mark. The wear of different kinds of equipment varies so widely that it is difficult to strike a proper average without long study of carefully and clearly kept records of life and up-keep.

Still another method of getting an idea of the depreciation of a plant is to obtain an appraisal of its value at some definite period by an expert of disinterested views, the differences between the original investment and the appraisal representing in individual items the diminution in value which has occurred. Two or three independent appraisals should throw considerable light upon the subject, especially if they are compared with the records of equipment life, which should be carefully kept. Data of this character are scarce, but if the matter were taken up more generally, a fund of knowledge would ultimately be accumulated which would be of the greatest value.

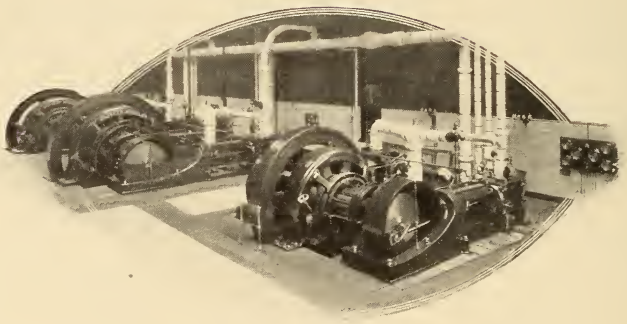
The line between depreciation and maintenance is often but faintly drawn, and in many quarters much confusion exists as to the difference between the two. In fact, it is common for companies to combine the two under a single head, when the actual expenditures have been purely those of maintenance. In some cases, companies claim that by charging all repairs to maintenance the property is kept in "as good as new" condition,—a claim which an appraisal shows clearly to be incorrect. For example, a steam locomotive costing, say, $16,000, is placed in service on a railroad, and during the first five years the cost of repairing it and thereby keeping it in good operating condition averages, say, $1200 per annum. In spite of this expenditure, the locomotive is obviously worth far less at the end of the five years than when it was new; very likely it is worth but from $8000 to $9000, and this in spite of the fact that it has been inspected at the end of each run of 100 miles and maintained in as perfect condition as the repair shops could accomplish. Depreciation is the disease which has caused this wasting away in value from the first cost; otherwise the locomotive might be operated perpetually.

Intimately associated with the depreciation question is the problem of reconstruction. In some cases, no reserves are kept, the cost of rebuilding being charged to the capital account. The opposite policy is to charge renewals and betterments to operating expenses. Thus, a railway relays a hundred miles of its main line with 100-pound rails, where 85-pound sections were previously used. It may reasonably be urged that the income capacity of the road is not increased appreciably by this step, and that the functions performed by the old equipment are not in the least altered. At the same time the property is actually improved and the investment in it is enlarged in value.

Hence the argument that capital should be increased to keep pace with the expanding assets.

The practice of the Massachusetts Railroad Commission—a notably conservative and yet progressive body—in respect to reconstruction charges has often been stated, but it may be emphasized here as an indication of just policy with reference to the perplexing question of betterments. In the case of both steam and electric railways, when reconstruction is effected, the Board makes an impartial appraisal of the work performed, charges to maintenance the estimated cost of replacing the original layout or equipment, and charges to the capital account the difference between this estimated cost and the actual cost of the work from the records of the company. In the majority of cases the cost of the new work exceeds by a considerable sum the appraised valuation, because the growth of the company's business, depending, as it largely does, upon the development of the territory served, demands the installation of heavier plant.

It is much to be desired that more definite knowledge of the life and maintenance of equipment should be acquired, not only by the accounting departments of both large and small industrial companies, but by their executive and technical officials, and the engineering profession as a whole. The conditions of operation must be known in general, no less than the bases upon which depreciation is to be figured. In this whole matter of depreciation and maintenance lies a splendid opportunity for investigation.



COMMERCIAL MOTOR VEHICLES

By J. F. Gairns

PART I.—STEAM MOTOR VEHICLES

IN popular estimation, the principal application of mechanical motive power to road traction is in connection with the ordinary motor car for private and pleasure traveling, though motor omnibuses are now attracting considerable attention, but from a business point of view, the large motor lorries and vans of various kinds now being introduced so extensively in Great Britain, and to a somewhat lesser degree in Germany, France and the United States, are far more important. In fact, while the supersession of the horse for passenger transport is largely a matter of private convenience and luxury, the use of motor vehicles for goods traffic and other commercial purposes is a matter of business finance.

The term "commercial motor vehicle" is generally used to describe any vehicle having its own mechanical motive power and adapted for the carriage of goods of various kinds, though it is sometimes used elastically to cover "tractor" vehicles or practically modified traction engines which convey all of the load in "trailer" vehicles. It is usual, too, that

FIG. 1.—A 4-TON COVERED VAN BUILT BY THE YORKSHIRE PATENT STEAM WAGON CO., HUNSLET, LEEDS

FIG. 2.—A 5-TON FLAT LORRY BUILT BY THE YORKSHIRE PATENT STEAM WAGON CO.

motor vans and lorries are designed to haul trailers so that the carrying capacity is very largely increased.

The principal kinds of vehicles which are described as "commercial motor vehicles" are light delivery vans, heavy vans, light lorries, heavy lorries, special motor vans, dust, watering and other municipal wagons, tipping wagons, girder wagons, etc. In many cases these are differentiated only by the nature of the superstructure provided. For example, a heavy van may be, as regards its engineering features, a replica of a heavy lorry built by the same firm. Correspondingly, too, as a connecting link between the private car and the commercial vehicle, the light delivery van may be identical, except for the body, with an ordinary passenger car. But for all practical purposes it is correct to say that the design of commercial motor

FIG. 3.—A 5-TON FLAT LORRY BUILT BY MESSRS. T. COULTHARD & CO., LTD., PRESTON

vehicles is a special branch of the motor vehicle industry, and, as a rule, engineers proceed on essentially different lines from those followed in the production of touring and private cars.

For the smaller and private types of motor vehicles "explosion" engines are almost universal, the successful designs which comprise a steam engine being comparatively few; but for the heavier vehicles, the reverse is the case, and for loads of more than about 3 tons the internal combustion motor is rarely used. This is due largely to the fact that the "explosion" motor is a comparatively delicate machine, and when great power is required at slow speeds, it is not the most suitable engine; whereas, the steam engine is more ordinary in construction, it can be designed to exert great power, it is more adaptable for greatly-varying circumstances, and it can more readily be built to withstand travel over rough and severely-graded roads at reasonable speeds with heavy loads. Moreover, with commercial vehicles, the presence of a boiler and furnace is not a matter of serious consequence, whereas, unless of special design, as in the case of Serpollet, White and other cars, the heat and fumes may be drawbacks for passenger vehicles.

For colonial and country use, the steam vehicle is a practical necessity, as the difficulty of obtaining "petrol" or other motive fluid for explosion motor vehicles is almost prohibitive.

Considerable impetus has been given the industry by the various reliability trials which have been carried out during the past few years, and in Great Britain by the exhaustive War Office tests conducted under government control. In these trials the utmost publicity results, for all the technical and many of the ordinary journals discuss freely the achievements of each competing car, and their respective merits and demerits are well advertised. Moreover, there is keen competition between the various firms, each endeavouring to produce the best and most satisfactory machines. Difficulties and severe conditions are courted rather than shirked, with a view to rendering the vehicles as perfect as possible however unpropitious circumstances may be, for it is the vehicle that can always be depended

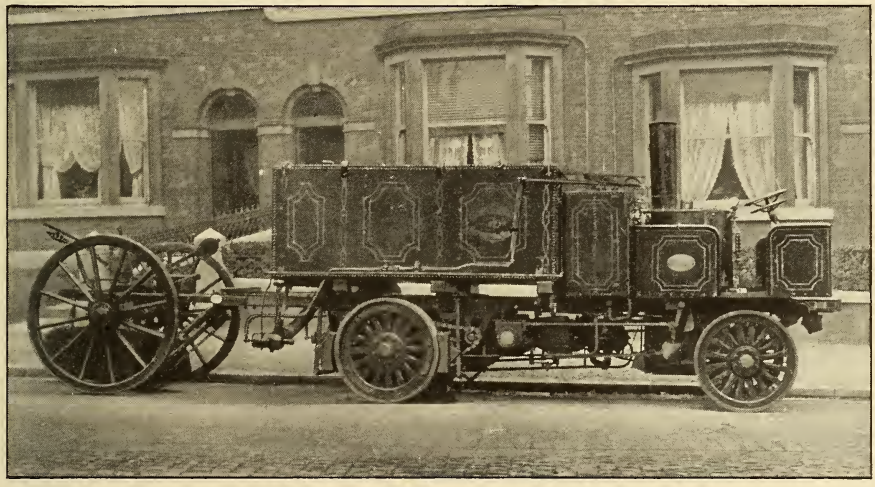


FIG. 4.—STREET SPRINKLER AND SWEEPER FOR MUNICIPAL USE. BUILT BY MESSRS. T. COULTHARD & CO., LTD.

FIG. 5.—A 1-TON EXPRESS DELIVERY VAN BUILT BY MESSRS. CLARKSON, LTD., OF CHELMSFORD

upon with only average skilled attention, and with good economy and freedom from breakdowns, that will obtain the business, which it is, of course, the aim and object of every manufacturer to secure.

While speaking generally of vehicles for colonial service, it may be mentioned that the circumstances of work oftentimes require considerable modification before the ordinary motor lorries and vans can be made suitable for such use, though manufacturers are only just beginning to realize this fact. The following considerations, as stated to the writer by the engineer of a well-known British firm, are worthy of note:

1.—Large fuel and water storage capacity is necessary.

2.—The engine and gearing must be specially easy of access while the vehicle is loaded, and simple enough in design to permit of repair by only generally skilled drivers.

3.—The steering gear must be of a type that if anything goes wrong it shall be the most easily replaced and most accessible part that will give first. For this reason, a few firms use the ordinary traction-engine type of chain-steering gear.

4.—A very low-speed gear is necessary, so that when traveling on very rough roads with numerous humps and deep ruts, a maximum of power can be exerted to extricate the vehicle from difficult situations. Some firms also provide a drum on the engine or intermediate shaft, so that the vehicle can be pulled out of difficulties by cable haulage, using a tree or rock as a hauling resistance.

5.—The boiler, engine and gear box must be placed high, as the vehicle is often required to ford rivers and streams.

6.—Broad and comparatively large driving wheels are generally necessary.

With the heavier types of vehicles, for dealing with loads of 4 or 5 tons and upwards, whether for home or colonial use, it is very often required that trailer vehicles shall be hauled so that the actual load conveyed is much greater than that which can be carried by a single vehicle. The engine and boiler, consequently, have to provide power for the complete

train. It has been proposed that the motor vehicle constitute a traveling electric generating station,—a dynamo driven by a steam or other engine, supplying current for motors on the axles of the power vehicle and on those of a series of trailer vehicles. The writer is somewhat doubtful as to whether this scheme has ever been carried into practice.

As regards the use of stored electric power for heavy vehicles, the great weight of the necessary accumulators for vans and lorries is against the use of this motive agent, though some electric vehicles will be described in this article; for the lighter delivery vans and like vehicles, electricity is used to some extent.

As before stated, the use of the heavier motor vehicles is most general, at present, in Great Britain; indeed, some authorities have expressed the opinion that the freedom allowed there in respect of size and weight is more than it should be, in view of the fact that roads are maintained at the expense of the ratepayers for general traffic purposes, and not specially for enabling individual firms to convey goods which until recently would have been transmitted by rail or water. The vibration, and the wear and tear which now occur to a great extent on main roads are neither good for roads nor buildings, not to speak of the noise and rattle made by these vehicles on cobbled and similar roads.

Recent legislation in Great Britain has provided rules and regulations to control the loads per axle, and the total loads permitted for these vehicles, but there is a fairly general opinion that the limits are placed too high for the public well-being as distinct from the interests of firms concerned. However, be this as it may, the present status of the commercial motor vehicle is very good, for nearly all firms having a large cartage business use them, and the loads dealt with are noteworthy, while the general efficiency and freedom from breakdowns reflect great credit on the builders.

FIG. 6.—A LAUNDRY VAN BUILT BY CLARKSON, LTD.

In this article it is intended to

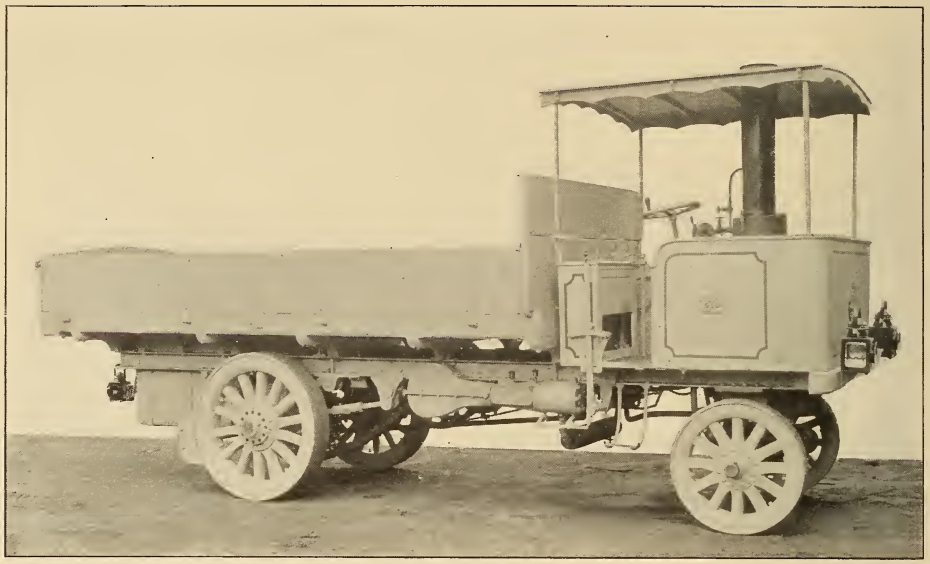


FIG. 7.—STEAM LORRY WITH HINGED SIDES AND TAILBOARD. BUILT BY THE BRISTOL WAGON & CARRIAGE WORKS CO., LTD., BRISTOL

review as thoroughly as space will permit, the principal designs and classes of commercial motor vehicles now on the market. At present, the largest business is done in Great Britain, especially for the very heavy steam vehicles, and therefore a majority of the vehicles to be described will be of British manufacture; but the work done in America and on the Continent is of considerable importance, and is being rapidly developed, so that before long these vehicles will be as common in the large towns of other countries as they are to-day in London and the principal cities of Great Britain.

As already remarked, steam is in great favour, in Great Britain at all events, as motive power for heavy commercial vehicles, and consequently representative steam vehicles will

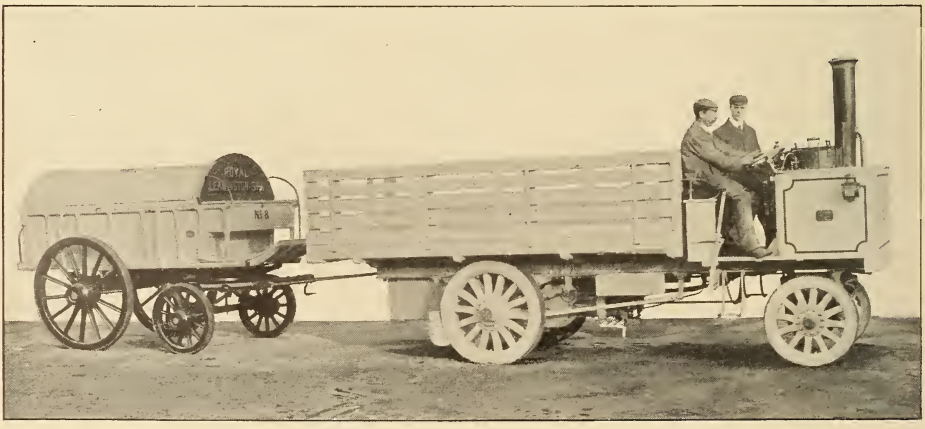


FIG. 8.—STEAM VAN WITH TRAILER MUNICIPAL WAGON ATTACHED. BUILT BY THE BRISTOL WAGON & CARRIAGE WORKS CO., LTD.

first be described. In dealing with these, it will be most convenient to consider the work of the various firms, in order, rather than to attempt to classify the vehicles, many of which are only differentiated by the nature of the body and superstructure provided. The engineering features of special interest will be briefly reviewed in connection with the work of each firm.

Fig. 1 shows a large van built by the Yorkshire Patent Steam Wagon Company, of Hunslet, Leeds. The boiler is placed longitudinally, and is designed on locomotive principles. It comprises two short horizontal barrels extending on either side of a central fire-box depending below the boiler. From the fire-box fire tubes extend each way to narrow smoke-boxes at each end; from these latter, return tubes pass to a central combustion chamber over the fire-box, and which is surmounted by the chimney. The exhaust steam is supplied to the smoke-boxes through small jets projecting into each of the return tubes above mentioned, thus serving the purpose of a blast pipe, and the steam is superheated in the combustion chamber so that a silent and invisible exhaust is obtained.

Gas coke is preferably used as fuel, and the boiler is found capable of maintaining pressure and water level with full loads up long, steep hills. About 1 cwt. of fuel is consumed per 10-mile loaded journey. Spur gearing is used exclusively, hinged brackets and guides being provided to support the intermediate shaft. The cylinders and motion are outside the frames, so as to be easily accessible even when the van is loaded. A long stroke is employed, and the engine is run at a moderate speed. Dust-proof casings are provided for the whole of the mechanism. The gearing provides for two speeds, usually for $2\frac{1}{2}$ and $5\frac{1}{2}$ miles per hour, and differential gear is fitted on the main axle. A single eccentric reversing valve gearing is employed. The front axle is free to rock on the fore-carriage springs. The road wheels are of the gun-carriage type, and the driving wheels are driven through drag rods to minimize strain. The van illustrated is a good average example of practice, and is classified as a 4-ton covered waggon.

Fig. 2 shows a 5-ton flat lorry built by the same firm. In all essentials, this vehicle corresponds to the van above described, but is slightly more powerful. In most cases, vans are provided with fuel and water capacity for about 40 miles per day. Similar vehicles are built having tank and cased-in bodies, and in some cases, particularly as supplied for municipal use, the bodies are adapted for end tipping.

The firm of T. Coulthard & Co., Ltd., of Preston, is well known for work they turn out. They have, moreover, introduced their vehicles into the United States, and entered the exhaustive trials conducted in New York by the Automobile Club of America for commercial vehicles, in May, 1903, when a gold medal was obtained. It is claimed that in these trials the Coulthard lorry carried the greatest paying load in relation to tare weight, covered the greatest number of ton-miles, cost less per ton-mile than any other vehicle, and mounted with comparative ease the steepest grades, which presented serious difficulties for several other cars.

Fig. 3 shows a flat lorry built by this firm, of the same class as that used in the American trials referred to, and adapted for a carrying load of 5 to 6 tons; its tare weight is about $4\frac{3}{4}$ tons. It is adapted for mounting with full loads grades up to about 1 in 10 on good roads. The boiler is vertical, having an upright fire-tube centrally fed from the top. A boiler pressure of 200 lbs. per sq. in. is used. The furnace is provided with a special system of fire-bars which can be easily and quickly dropped. The fuel is coke or coal, but preferably the former.

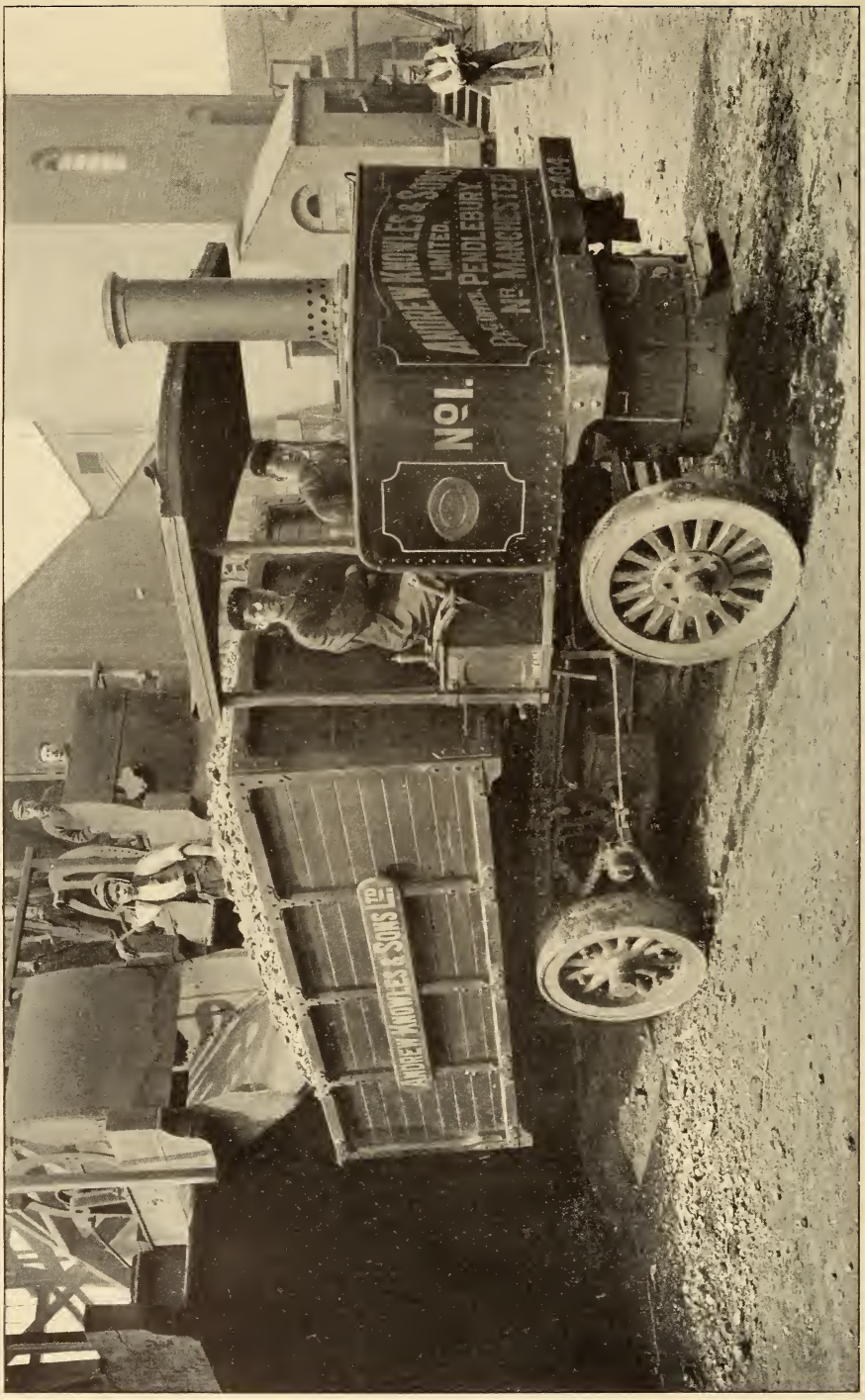


FIG. 9.—A STANDARD 5-TON TIP WAGON BUILT BY THE LANCASHIRE STEAM MOTOR COMPANY, LTD., LEYLAND

The engine is horizontal, having two cylinders working compound. Two gears are provided for 5 and 2½ miles per hour, respectively. To allow for variation in loading and uneven roads, a system of spherical bearings and flexible joints is fitted. Fuel capacity for 4 cwt., sufficient for about 30 miles' journey, is supplied, and water storage for 12 to 15 miles. The wheels are of gun-carriage pattern, having diameters of 3 ft. rear and 2-ft. 9-in. front. Silent-running chains are used for transmitting motion.

As an example of the use of these vehicles for municipal purposes, a street sprinkling cart with a sweeper attached, as supplied by Messrs. T. Coulthard & Co., Ltd., to the South-end-on-Sea Corporation, is shown in Fig. 4. This vehicle, so far as the frame and engine is concerned, corresponds to the class "C" lorry adapted for a load of from 4 to 5 tons. The water tank and special fittings constitute the only constructional differences.

It may be mentioned that motor vehicles for street watering and sweeping, and for collecting household refuse are now used very generally in all the large British cities, and that machines of these descriptions are built by every maker of steam commercial vehicles. When used for dust and refuse collection, covers are generally fitted, and the body is provided with tipping gear. Messrs. Coulthard's lorries and vans, when hauling trailer vehicles, can deal with total loads of more than 8 tons.

The firm of Clarkson, Ltd., of Chelmsford, is now in the foremost ranks of steam-motor vehicle builders, but as regards commercial vehicles, they are principally concerned with lighter vans. In most cases the Chelmsford cars, to use the trade name usually associated with all vehicles built by this firm, are fired with liquid fuel; the boiler and fuel burners employed, which are the subjects of numerous patents, are of a special design, and the proper regulation of fuel and water supplies has received particular attention.

As a rule, ordinary paraffin oil is used, so that the objections to the lighter oils, particularly for service in hot countries, are obviated, while

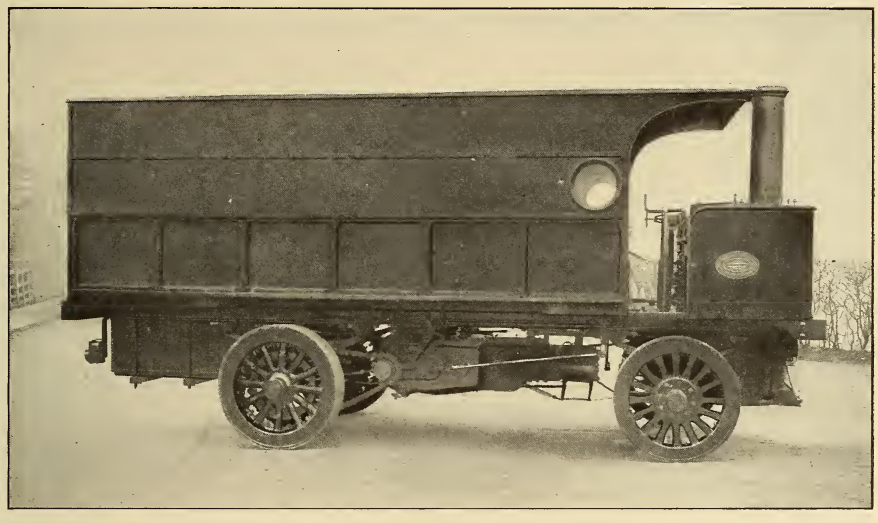


FIG. 10.—STANDARD 5-TON COVERED VAN BUILT BY THE LANCASHIRE STEAM MOTOR CO. LTD.

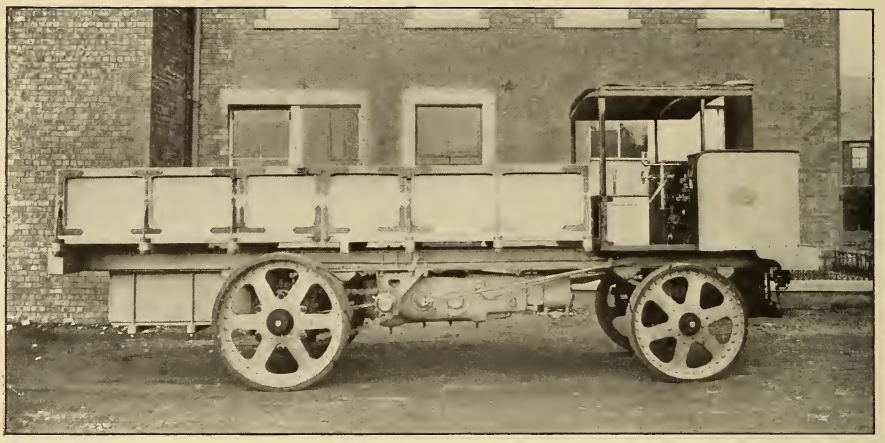


FIG. 11.—A STANDARD 6-TON COLONIAL WAGON BUILT BY THE LANCASHIRE STEAM MOTOR CO., LTD.

cheapness and facility of obtaining a fresh fuel supply are important advantages. The exhaust steam is condensed, so that water supply is economized. All the working parts are enclosed, and an efficient lubrication system is supplied. It may be mentioned that several steam fire engines in use in London are equipped with the Clarkson burners for service while standing at the fire brigade station, and by their use a fire call can be responded to and steam raised in about 2½ minutes.

Fig. 5 shows a 1-ton Chelmsford delivery van, and this is a good example of the lighter practice of this firm. A similar style, except as regards the superstructure, is used for various types and sizes of vans and for steam omnibuses, of which Messrs. Clarkson make a specialty, many of their 'buses being in use in various parts of Great Britain.

FIG. 12.—TANK WAGON WITH STREET SWEEPER ATTACHED. BUILT BY MANN'S PATENT STEAM CAR & WAGON CO., LTD, LEEDS

In Fig. 6, a heavier type of van, adapted for laundry use, is shown. In this case, loads of over 2 tons can be dealt with, and corresponding lorries are built. The Clarkson boiler is tested hydraulically to 700 lbs. per sq. in., and by steam to 400 lbs. per sq. in. It is fitted with twin safety valves blowing off at 350 lbs. per sq. in. A steel superheating tube is fitted close beneath the lower tube plate of the boiler. The cylinders are small, though, owing to the high pressure used, large power can be developed. A Joy's valve gear is provided; and for the condenser and radiator, special wire-wound tubes are employed.

Another well-known firm concerned with heavy lorries, and like vehicles, is the Bristol Wagon & Carriage Works, Ltd., of Bristol, and two of their vehicles are illustrated in Figs. 7 and 8. In the former case, a lorry having hinged sides and tail-board, so that it can be used either flat or with the sides and end raised, is shown. This vehicle is fitted with chain-driving gear.

In Fig. 8 another type of van having crib sides is shown, and in the illustration a trailer municipal van is represented attached. The engine is arranged below the frame, instead of at the sides, as in Fig. 7, and the gearing and mechanism are differently arranged. The boiler fitted in Fig. 7 is of the water-tube type, while that in Fig. 8 has a vertical fire tube, and fuel is supplied from the top. The engines fitted are two-cylinder compound.

Figs. 9, 10 and 11 show three representative vehicles built by the Lancashire Steam Motor Co., Ltd., of Leyland. These views represent, respectively, a 5-ton standard-tip wagon receiving a load, a 5-ton standard covered van supplied to the Royal Gunpowder Factory at Waltham Abbey, Essex, and a 6-ton colonial wagon.

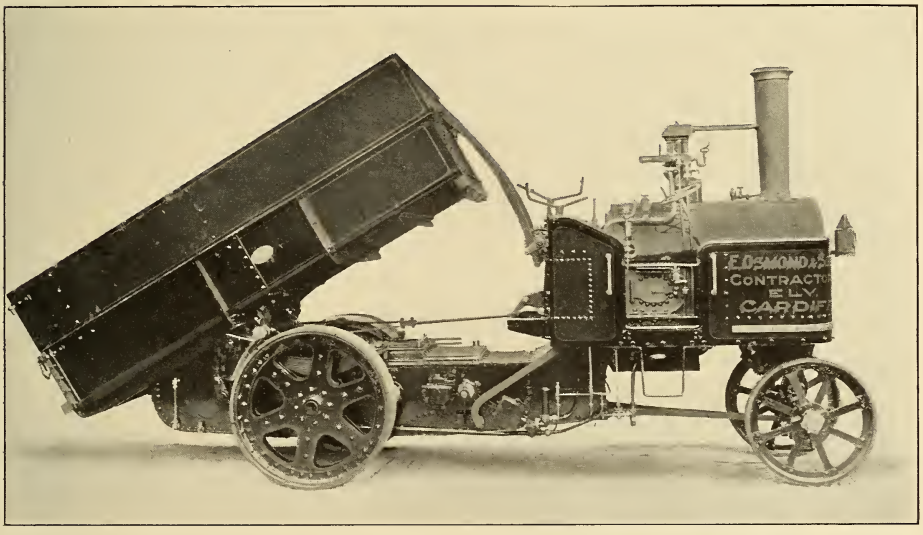


FIG. 13.—A STANDARD TIPPING WAGON BUILT BY MANN'S PATENT STEAM CART & WAGON CO., LTD.

The Leyland boiler, to use the trade name of these engines, is of the fire-tube central-feed type, adapted for a working pressure of 200 lbs. per sq. in. A special feature of this boiler is the facility provided for its disconnection for repair and cleaning. The engine is of the two-cylinder compound horizontal type. A peculiarity of this engine is that all

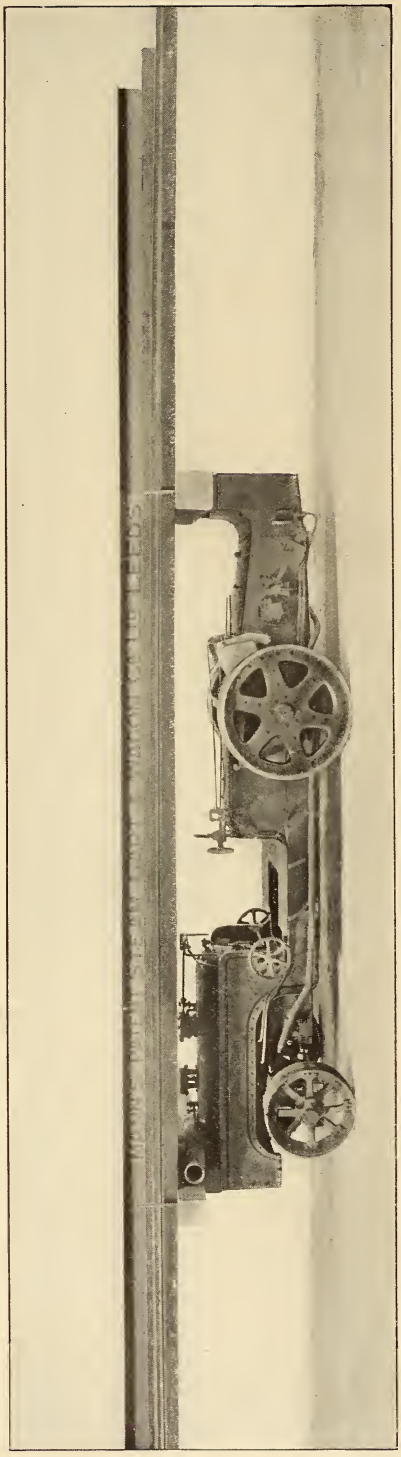


FIG. 15.—SPECIAL GIRDER WAGON BUILT BY MANN'S PATENT STEAM CART & WAGON CO., LTD., LEEDS

the bearings are non-adjustable, as the bearing surfaces are very large. The gearing gives two speeds,—5½ and 2½ miles per hour.

The vans shown in Figs. 9 and 10 may be taken as representative of general practice. They are made to carry up to 8 tons, though about 5 tons is the usual capacity provided for, with the ability to haul one or two trailers.

The colonial wagon shown in Fig. 11 is similar in general appearance to the ordinary British vehicles, but there are several special features provided for. The wheels are of steel, instead of wood, and the body is given a greater clearance than usual, so as to allow of the fording of rivers. The boiler is specially designed so that dirty water can be used without causing too much trouble. The gearing is arranged so that the engine can make nearly a complete revolution before the driving wheels start moving. Provision is made for admitting live steam to the low-pressure cylinder in starting. The whole of the gearing is enclosed and runs in oil. The brakes are arranged inside the large chain rings, and are of the expanding type.

In the case of municipal and similar wagons, many of them are provided with interchangeable tipping tank and garbage bodies, and provision is made so that with the aid of a crane either can be readily fitted on the frame. The writer is informed that over 200 steam wagons have been supplied by this firm, and, although the same can probably be said of several other firms, though actual figures cannot be quoted, it is strong evidence as to the extensive use of such vehicles in British business.

One of the most important firms dealing with vehicles of the kind under notice is Mann's Patent Steam Cart & Wagon Co., Ltd., of Leeds. Figs. 12 to 15 show representative vehicles built by them. From these illustrations it will be seen that traction engine practice is followed in

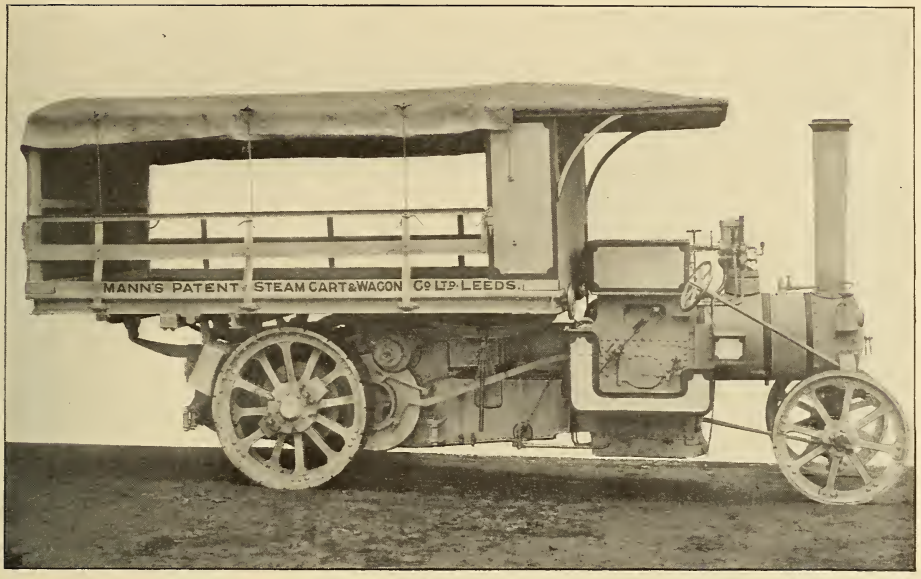


FIG. 14.—STEAM VAN OF TRACTION ENGINE TYPE BUILT BY MANN'S PATENT STEAM CART & WAGON CO., LTD.

many respects, especially as regards the boiler, steering gear and framing. The power is transmitted by spur gearing, without chains. The engine is two-cylinder compound and runs in a closed oil bath together with quick-running gearing. The boiler is of the locomotive type and is made detachable, except in the case of small vehicles, so as to facilitate repairs.

Fig. 12 shows a municipal tank wagon having a tipping body, and adapted for the attachment of a sweeper. Fig. 13 illustrates very effectively a standard tipping wagon. Fig. 14 represents what is practically a small traction engine with a rear frame attachment for the load, a wagon body being provided. Similar wagons with flat lorry and other bodies are built extensively.

The wagon shown in Fig. 15 is of a type that is little known, in fact the writer knows of only two firms who build vehicles for this service, and that represented is one specially designed for dealing with long girders and similar long iron work. The wagon differs very considerably as regards appearance from the ordinary practice of this firm, but, except for the special arrangements, the parts correspond generally with ordinary methods. The boiler is arranged very low down, and the chimney is carried out sideways. The end frames are adapted to provide supports for the girders as shown.

Another of the principal British firms concerned with heavy steam vehicles is that known as the Straker Steam Vehicle Co., Ltd., of London. This firm occupies a leading position in connection with the development of these vehicles, and a very large business is done by them. The variety of their vehicles is almost endless, and while as a general rule the cars are of types similar to those illustrated in connection with the work of other concerns, there are a number of specially interesting vehicles to be credited to this firm. The general types of vehicles are common for every firm, but in some cases the writer is able to give prominence to special vehicles, while in other instances principal business is done with more ordinary types.

A few notes concerning the engi-

FIG. 16.—A 5-TON SIDE-TIPPING WAGON. BUILT BY THE STRAKER STEAM VEHICLE CO., LTD., LONDON

neering features of the Straker vehicles will be in place before describing actual productions of the builders. The boiler comprises four concentric circular shells, and the two inner and the two outer of these form between them annular water spaces. These water chambers are connected by radially arranged tubes, and the furnace gases pass round and between these tubes. The innermost shell forms a closed heating chamber and is used for supplying fuel to the furnace, the central flue being fitted with a removable cover at the top. The gases passing between the tubes are

FIG. 17.—A COLONIAL WAGON OF SPECIAL DESIGN BUILT BY THE STRAKER STEAM VEHICLE CO., LTD.

conveyed to the chimney. Coke or Welsh coal is used as fuel, except for colonial purposes, when wood is, of necessity, generally employed. Before passing to the engine the steam traverses two armoured coils arranged around the firebox, so that it is superheated.

For light vehicles small high-speed engines are used, but for the heavier vehicles long stroke, comparatively slow-speed engines are employed. Two cylinders are used, horizontally arranged and working compound. A single eccentric reversing valve gear is fitted, and the valves are of the piston type.

The Straker engine is peculiar in that a small fly-wheel is used. The gearing is specially constructed and arranged in some vehicles to give as many as six speeds, one set of gearing providing for three variations, while an intermediate clutch gear duplicates these,—but in the ordinary way two or three speeds only are provided for. The steering gear is of the worm type in most cases, adapted for a special front axle suspension, but in some cases, particularly for colonial service, the ordinary traction engine style of mechanism is employed as being most suitable and most easily repaired and replaced.

Fig. 16 illustrates a representative Straker wagon, and from the photograph a good general idea as to the external characteristics will be obtained. This particular vehicle is, moreover, interesting, as it is fitted for side tipping. The height of the body upon its supports is a necessity for side tipping. The capacity of the wagon shown is 5 tons, so that there is no sacrifice of carrying capability in order to provide for side tipping, as one might presume from appearances to be the case. For vehicles of this class, trailer cars having similarly high pitched side-tipping bodies are sometimes provided.

All ordinary types of lorries, vans, end-tipping wagons, tank wagons, etc., are built regularly by this firm for loads from about 2 tons up to 7 or 8 tons. In some cases, hauling

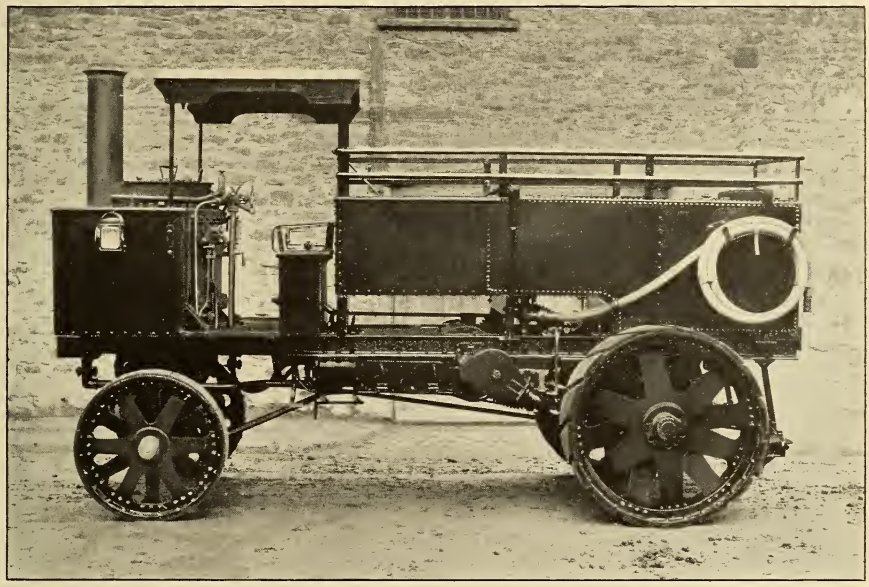


FIG. 18.—STEAM TRACTOR WITH LARGE WATER AND FUEL STORAGE PROVISION. BUILT BY THE STRAKER STEAM VEHICLE CO., LTD.

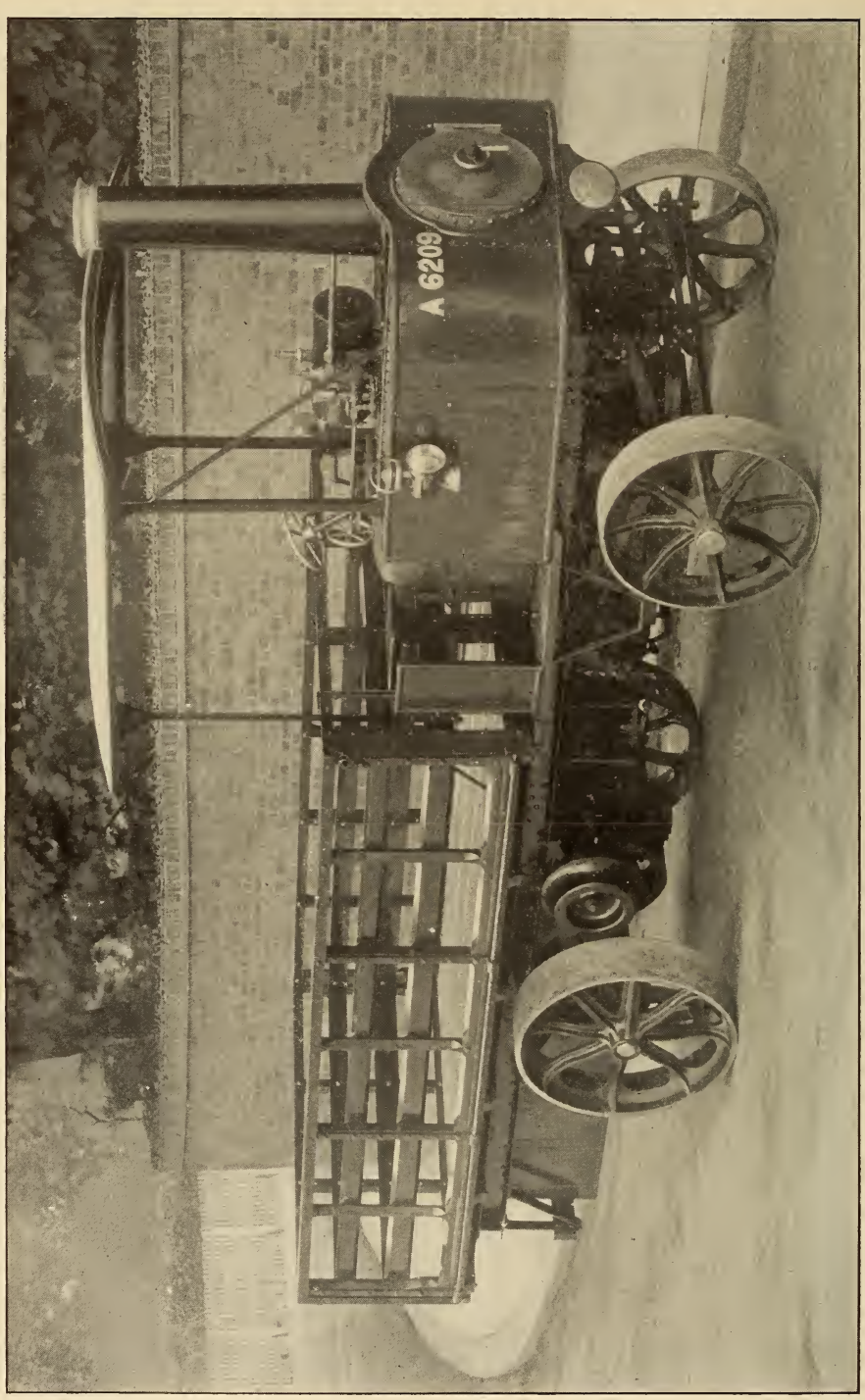


FIG. 19.—A 5-TON STEAM LORRY BUILT BY THE THORNYCROFT STEAM WAGON CO., LTD., BASINGSTONE

FIG. 20.—A 5-TON STEAM LORRY BUILT BY MESSRS. JESSE ELLIS & CO , LTD., OF MAIDSTONE, KENT

gear operated from the engine is fitted to assist in drawing loads on the lorry platform, and this facility can be very useful at times in dealing with awkward loads, especially when a loading crane is not available or is inconveniently situated for use. A number of omnibuses have also been supplied by this firm, the principal differences being the provision of higher speed gearing, and, of course, an appropriate body.

In the introduction, special stress was laid upon the conditions which govern the designs of vehicles for colonial use; a vehicle built specially to satisfy such requirements has been recently constructed by this firm, and is now undergoing severe War Office trials. This wagon is illustrated in Fig. 17, and the following particulars will be of interest:—

The wagon is adapted for a load of 7 tons and for working over rough roads with severe gradients; it is designed for the special difficulties which colonial use often entails. The length is 22 feet, with a wheel base of 12 feet 5 inches, and a wheel gauge of 6 feet 4 inches, reckoned from the centers of the driving tires. With the full load it will ascend gradients of 1 in 6 on ordinary roads, and with a loaded trailer adapted for from 3 to 5 tons grades of 1 in 10 can be negotiated.

Three gear speeds are provided for, giving speeds of 2, $4\frac{1}{2}$ and 7 miles an hour. When the lowest speed is employed, the machine should be able to exert sufficient power to enable it to extricate itself from almost any difficulty; but by means of a hauling drum fixed to the back axle, and a steel cable, an additional means of haulage is provided for use where ground conditions prevent the vehicle exerting its power properly, so that even the most severe hindrances can be overcome. Large driving wheels

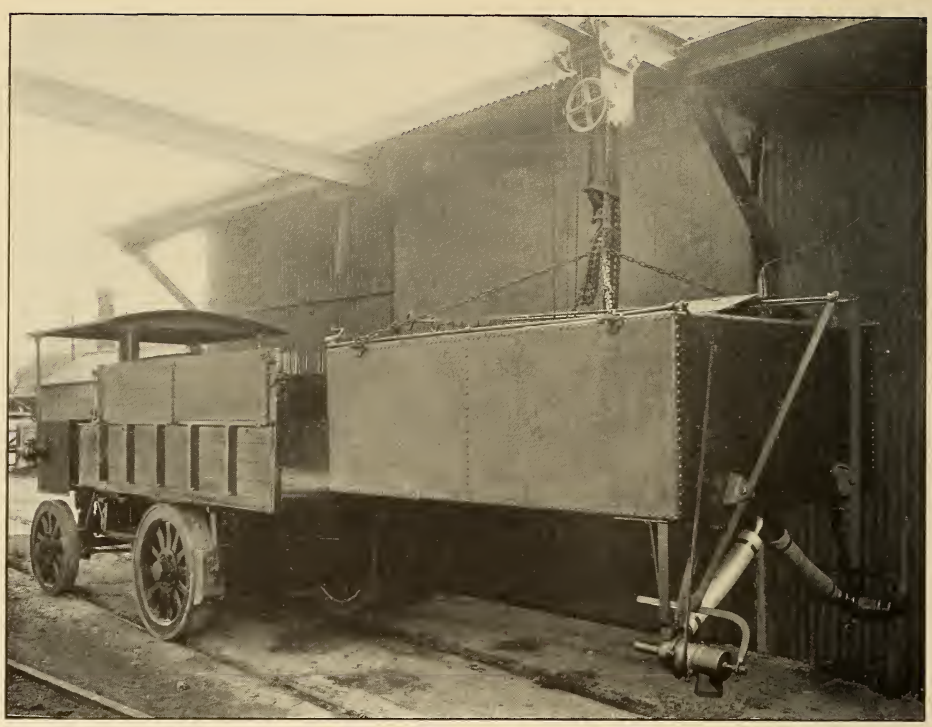


FIG. 21.—STEAM VAN WITH INTERCHANGEABLE BODY, SHOWING TANK EQUIPMENT SUSPENDED AND READY FOR SUBSTITUTION. BUILT BY MESSRS. JESSE ELLIS & CO., LTD.

5 feet in diameter and 14 inches wide on tread are employed, constructed on traction engine lines.

A number of special fittings are provided, including a steam water lifter, and there are many other features, though usually corresponding to general practice as outlined above, to which space considerations prevent further reference. Traction engine type steering gear is used for the reasons previously stated.

Before concluding references to the work of this firm, attention should be called to the colonial steam tractor illustrated in Fig. 18. This vehicle is not intended for conveying any load itself, all the load being conveyed in two or three trailers, or even as many as six trucks or wagons. This vehicle is particularly adapted for use in colonies where water supplies are comparatively scarce, being provided with very large water storage tanks. Wood fuel can be carried on top of the tanks.

The firm of J. I. Thornycroft & Co., Ltd., of Basingstone, is well known in connection with motor vehicles of many kinds, and in Fig. 19 a representative steam wagon built by them is illustrated. It is adapted for a load of 5 tons, with 2 tons on a trailer, at a speed of 6 miles per hour. The engine is of the two-cylinder horizontal compound reversing type, provided with a special radial valve gear; chainless gearing is employed, and a central fired water-tube boiler is fitted. Vehicles of various types, with appropriate bodies and superstructure, are built, the one here illustrated being of the lorry type, with open work side and end frames.

In the cases of vehicles for colonial use, a special front carriage, fitted with a tilting front axle giving a three-point support and avoiding

racking strains on rough roads, is employed. The boiler has large grate area, and is adapted for burning indifferently coal or wood fuel. In some cases oil fuel is employed. A winding drum is provided, and other special fittings, such as those mentioned in connection with the Straker vehicles, are used. Power is provided, as in the case of most vehicles, for the haulage of trailers.

A considerable business is done by this firm in connection with petrol driven vehicles, and as this work is of great interest, more attention will be given it in the second section of this article.

Fig. 20 illustrates a steam lorry built by the firm of Jesse Ellis & Co., Ltd., of Maidstone, Kent, adapted for a 5-ton load and 2 tons on a trailer. The boiler is of the Ellis-Bamforth type, fitted with curved fire tubes arranged in rings around a central fire tube. Coke is the most general fuel employed, though the boilers are adapted for Welsh coal, wood and oil burning. A horizontal compound reversing engine with a long stroke is fitted with valve motion of the ordinary link type. Spur gearing is employed, as this firm, like so many others, finds it preferable to chain driving. The engine shaft carries a fly-wheel.

Vehicles of various types are built by this firm, and in many cases interchangeable bodies are provided so that one chassis can be made available for several purposes. For example, a van or tipping wagon body can be readily removed and a municipal watering cart body substituted. Fig. 21 shows such a wagon with the tank body suspended from a crane, ready for substitution.

Quite recently the Thames Iron Works have entered the field of commercial vehicle building, business being done under the name of "The Thames Engineering Works" at the Greenwich works, so long famous in connection with the firm of John Penn & Sons, Ltd. Many of their vehicles are of considerable interest, though the writer is unable to illustrate any of them. The boiler is of the locomotive type arranged longitudinally, while the engine, which is two-cylinder compound reversing, is arranged transversely. The engine is enclosed and fitted for automatic lubrication. A two-speed gear for speeds of 6 and 10 miles an hour is

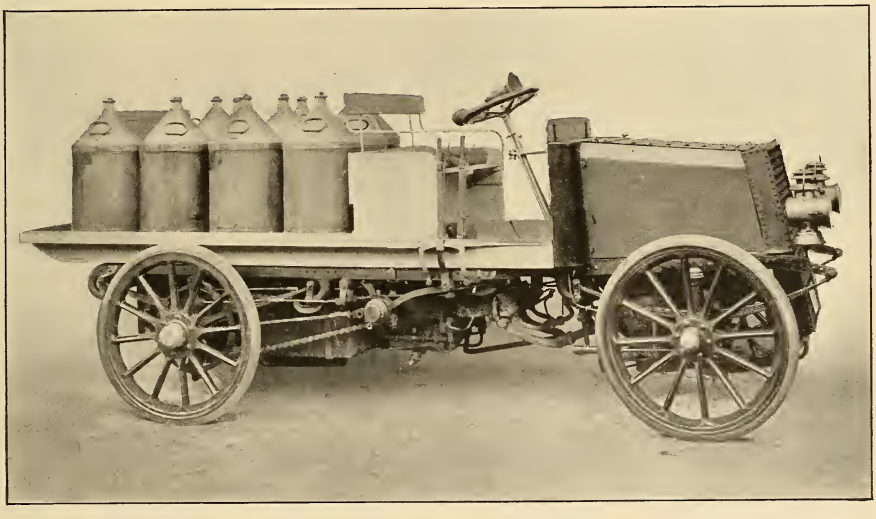


FIG. 22.—A 12-CWT. FLAT LORRY BUILT BY THE CREMORNE MOTOR MANUFACTURING CO., LONDON

provided, and spur wheels are used for transmission.

Besides the firms mentioned, there are several others concerned with work of the character under notice, and the vehicles turned out by them have a strong family likeness to the various lorries and vans previously described, the principal differences being comprised in the construction of the boiler, the design of the engine, and in connection with the speed gears, transmission, steering gear, suspension and other details, just as these matters principally differentiate a majority of the vehicles more extensively dealt with. A few of these firms will be mentioned, though the writer is unable to illustrate their vehicles.

The vehicles built by Fodens, Limited, of Sandbach, England, are designed to a considerable degree on traction engine lines, and in many cases they may be described as small traction engines having the frames extended backward to provide carrying accommodation. Indeed, unlike any of the vehicles hitherto described, most of the Fodens vehicles have the engine located above the boiler in true traction engine fashion. Two cylinder compound engines are generally fitted and adapted for using superheated dry steam. Tractor vehicles adapted to convey all of the load in trailers are also built. These are practically modified traction engines.

The Londonderry steam wagon built by the Seaham Harbour Engine Works corresponds in many respects to more general practice. The boiler is of the fire-tube, central-feed type. The engine is horizontal and two-cylinder compound, the slide valve being operated by a special single eccentric valve gear. Two-speed gearing provides for speeds of $2\frac{1}{2}$ and 6 miles per hour.

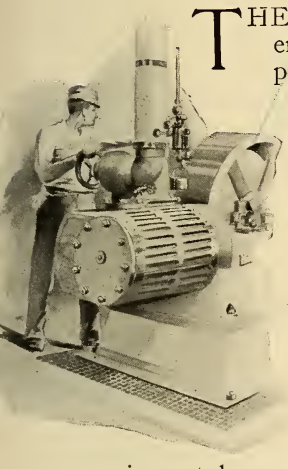
The Cremorne Motor Manufacturing Company make a specialty of lighter lorries and vans, but heavy vehicles are also built by them. A 12-cwt. lorry built by them is shown in Fig. 22. The boiler, located under the front bonnet, is of the multitubular type with vertical tubes, and is adapted for a working pressure of 350 pounds per square inch. An automatically controlled oil burner, regulated by the pressure, is used for the furnace.

The engine employed comprises four single-acting horizontal cylinders operated by a special valve gear in which a single valve controls the distribution for two cylinders, and a single eccentric actuates both valves. By means of a spiral sleeve, a reverse motion is obtained, and the cut-off can be varied from zero to about three-quarters stroke. The steam is superheated for use. The speed is principally controlled by varying the engine throttle valve and the reverse lever, and these are operated by foot pedals to some extent, so that the driver's hands are left free for steering.

The concluding part of this article, to appear in the August number, will be devoted to petrol and alcohol motor vehicles.

CHOOSING AN ENGINE FOR AN ISOLATED PLANT

By H. S. Knowlton



THE selection of a steam engine for isolated plant service is a problem too frequently settled without an adequate appreciation of its complication, and with little conception of the influence of the decision upon the total yearly cost of operation. In almost all commercial enterprises, the first cost of equipment has a greater significance to the purchaser than it probably should have. Less attention is paid to the less striking considerations of economical operation, and these in the long run often offset the fixed charges. Efficiency is almost always considered, as far as the ratio of output to input is concerned, but in many cases the comparisons go no further, the award going to the lowest bidder.

Judging the competitive propositions submitted and the claims and performances of rival makes of engines in reference to the anticipated conditions of operation is no easy piece of work, and it may well be entrusted to an engineer who has frequently made investigations of this character. At the same time it is well for the purchaser to have an intelligent appreciation of the desirable qualities of an engine, and this article aims to suggest a few points worth thinking about before the contract is awarded.

It is not to be expected that any single machine will embody all the most desirable points of the ideal engine. The design of steam engines is no less a series of judicious compromises than is the design of dynamos and motors. High efficiency is desirable, however, in all commercial machines, and by this is meant not only moderate or low steam consumption per indicated horse-power-hour at full load, but also a reasonably low water rate at fractional loads. Information as to the steam consumption of engines at various loads is therefore one of the first things to be sought before deciding where to buy. The more progressive manufacturers have no hesitation in supplying these figures, but in too many cases great stress is laid on the steam consumption at full load, and too little on the performance at from 25 to 75 per cent. of the normal rating.

Under modern conditions of isolated plant service, it is impossible to operate the engines at normal load continuously, and, for this reason, the water rate at half load and thereabouts is really more important than the rate at the full output. It may be urged that if an engine is selected of the proper size for its work, full duty may be imposed upon it through many hours of the day. This is one of those claims which are fair to look upon, but which are exceedingly difficult to realize in practice. If the load of an isolated plant were almost entirely lighting output, the problem would be greatly simplified, but when elevator motors, fans, and other power-consuming machinery are supplied from the plant, it is a matter of extraordinary difficulty to predict the precise average load which will be

imposed upon the engines at different hours of the day with different groups or combinations of machinery in service.

Scarcely any two installations are alike in the detailed service required, —otherwise it would soon be a cut-and-dried matter to pick out the sizes of engines desirable. Even if the load curve could be predicted with close accuracy before the contracts are awarded, some margin in power would still be desirable against extensions in the future above the temporary overload capacity of the machinery. Here enters the question as to what kind of an isolated plant one is considering, with all the complex conditions peculiar to different classes of service.

One is not likely to go far astray in determining the size of engines to be used before settling upon the type best adapted to the requirements. A large number of factors enter into this. One of the best things which can be done is to study existing installations in which the conditions resemble those of the new plant. Every installation teaches valuable lessons of what to imitate or avoid, if one has ability to see them. Given an office building, for example, with a certain number of stores and tenants and certain machinery installed, it ought to be a simple matter to ascertain if that machinery is adequately loaded or not, what are its hours of operation, the regular overloads to which it is subjected and the like. It is almost as serious an error to install equipment that is too heavy for the requirements of economical service as to put in apparatus of inadequate capacity. There is good reason for determining both the ratio of average to maximum load and the ratio of average to total connected load if judgment of desirable machine sizes is to be sound.

Although in some recent cases, known to the writer, isolated plants have been built with but a single generating unit, the practice cannot be condoned except in instances where reserve power is available from the distributing circuits of a local central station. Even the use of a storage battery auxiliary will tide such a plant over but a brief period, and a prolonged breakdown caused by some accident to the engine or generator which cannot be repaired within a few hours is surely the most exasperating embarrassment. Continuous service is too important a feature of modern business requirements to be hazarded by such short-sighted placing of all one's eggs in a single basket.

About the best that can be done is to select engines of a size that will enable them to be operated between 50 and 125 per cent. of normal load whenever they are in service. Since the average load on a plant varies considerably throughout the day, one cannot expect to follow it exactly with fully loaded machines when there are only two or three units in the plant; but with care in the selection of sizes, and close study of what similar installations are doing, it ought to be possible to operate with good economy during most of the day.

The best practice inclines toward the use of only two sizes of machinery in the engine room. These should be far enough apart so that there will not be an overlap in the economy of steam; that is, when the load which could be handled most efficiently by the smaller unit occurs, it should be time to shut the larger engine down to save steam. Sufficient overload capacity to enable the more important sections of the installation to be operated for a few hours in case of trouble on one machine is very important.

Designs of engines now on the market show that the manufacturers have found so many ways in which to attain the same general ends that it is difficult for a layman to decide which type of mechanism is best suited to his requirements. In regard to valve motions, it is not the writer's purpose to discuss detailed designs, interest-

ing as they may be, but a few points may be noted which it is well to look for in purchasing an engine. Simplicity in the design of valves is desirable for the reason that the need and cost of repairs is generally less in valves of few parts. Provision for compensating for wear must not be overlooked, and the valve mechanism capable of remaining steam-tight after years of operation deserves consideration.

The highest economy in engine performance requires that the steam shall be admitted at a uniform pressure as near that of the boiler as is possible; that the cut-off shall be sharp and quick, so that the expansion may take place over the requisite range, and that the steam shall be discharged completely after expansion, with the exception of just enough to cushion the piston at the end of its stroke. Both admission and exhaust valves must open wide and very rapidly. Excessive friction in the operation of the valve mechanism is to be avoided, not only on account of the loss of power, but also on account of the additional wear and tear.

In a double-acting engine, clearance, or waste room in the ends of the cylinder and ports, is well understood to be a source of loss. Not only does it produce an increased terminal pressure relatively to the mean effective pressure, but it also means that a greater amount of steam must be exhausted at a given terminal pressure when the latter is in excess of the atmospheric pressure or that of the condenser, when one is used. It is a mistake, however, to assume that large clearance in every type of engine is a serious defect, for, in a prominent single-acting make, experience appears to have shown that its large high-pressure clearance, —comprising the port volume, the ordinary clearance between the piston and the end of the cylinder, and the volume around the neck of the valve, that space always being in connection with the high-pressure cylinder,—is the secret of the favourable economy of the engine under wide ranges of load. There are no free expansion losses in this case, as the clearance is never in communication with the exhaust.

In general, a large clearance must be looked at askance, because in addition to the increased space to be filled by the incoming steam, and consequent increased surface for cylinder condensation, the early exhaust closure incidental to excessive clearance prevents the complete escape of water from the cylinder, this water accumulating and assisting cylinder condensation. A prominent maker states "that excessive clearance of this character also increases the danger of a breakdown, for it is not usually water thrown over in a large quantity which wrecks high-speed engines, but rather an accumulation from stroke to stroke without proper means of escape, which finally demonstrates its incompressibility by knocking out the cylinder-head."

For isolated plant service in which the space available is restricted, and in which moderate-sized or small units are acceptable, the automatic engine, characterized by high rotative and piston speed, relatively short stroke, with a flywheel governor and dependent valve gear, finds a special fitness in application. Such engines can be made to regulate much closer than slower-speed machines, are especially adapted to direct connection, occupy but little space, are fairly moderate in first cost, do not require large and expensive foundations, and, in point of reliability, are often the equal of the best long-stroke, slower speed, automatic engines. Owing to their wide range of economical operation they often give better results in fuel economy than four-valve, slow-speed engines, which may show better figures at or near full load, but a proportional falling off at light and moderate outputs.

Since the most serious waste of steam in automatic engines is caused by cylinder condensation, the short-stroke, high-speed cycle is particu-

larly desirable in its suppression of this tendency.

Although theoretically there is a certain degree of advantage in respect to the friction obtained by a long stroke, experience has shown that if steam is to be used economically it must be worked quickly, and particularly so when expanded from three to five times, as in the automatic engine. Hence the shorter the stroke, the more quickly a given amount of expansion can be effected, and the less is the loss by condensation.

It has been pointed out by writers upon steam engine economics that the gain from reduced friction is not nearly so great as is generally supposed. The friction of journals is due mainly to two causes,—the force of the steam and the weight of the flywheel; and since the weight of the flywheel must, other things being equal, be inversely as the square of the revolutions per minute, the greater weight required in the flywheels of long-stroke engines neutralizes the gain, so far as the friction of the journals due to weight is concerned, and confines it to that due to the force of the steam. Long-stroke engines are sometimes inadequately provided with flywheel weight, otherwise less would be heard about the greater friction of short-stroke engines. Very high speeds, such as are attainable only with the most perfect workmanship and material and the highest order of skill in subsequent management are of course not desirable. An instance of the speed variation met in four prominent high-speed, simple engine designs may be cited for a single size,—100 H. P. at 100 pounds initial pressure and one-quarter cut-off:—

		Cylinder, Dia.,	Stroke,		Piston Speed, Ft.
Engine	H. P.	Ins.	Ins.	R. P. M.	per Min.
A	109	12	16	240	640
B	93	12	10	330	550
C	100	13	12	300	600
D	100	12	12	300	600

It is interesting to note that there is a difference of about 16 per cent. in the piston speeds, and about 27 per cent. in rotative speeds of the lowest and highest engines. Practice does not vary in the last two engines, and it is safe to consider their speeds as a fair average of good design, but there would seem to be hardly enough difference to warrant a choice from the speed standpoint alone. In comparing different propositions, a "line-up" of this character is always worth making, with additional data upon weights, floor space, first cost and steam consumption at various loads.

The exacting requirements of electrical work have been most influential in raising the standard of engine regulation in many different kinds of service, and particularly is this true in connection with the isolated plant, which almost always carries a lighting load of great commercial importance. At the present time, extra close regulation is sometimes insisted upon where small refinements are not needed, so that governors can be built and so adjusted that there will be no apparent difference in speed between no load and full load, or so that there will be an increase of one or two per cent. at full load. Such regulation is of little commercial importance, and as long as a governor has perfect steadiness and regulates within one or two per cent., little else need be asked. A simple design is of course commendable, but a prominent engine manufacturer has well said that he "knows no single maker of engines with any claims to prominence who builds an engine that does not regulate sufficiently well for any commercial purpose." It is really a matter for congratulation that the governor problem has been so well solved.

It is very important before purchasing an engine to anticipate its steam consumption at all loads from 25 per cent. of normal to 25 or 50 per cent. overload. The full load economy is actually a matter of small significance in isolated plants subjected to wide fluctuations of output. Consequently a guarantee should be

obtained from each of the bidders, showing exactly what the engine can be counted upon to do. The practice of supplying the purchaser with tests made at the factory under service conditions is a lasting mark of good faith, and it should be increased among progressive manufacturers. The purchaser should always remember that the amazingly low figures of steam consumption at full load submitted by bidders are often only to be realized upon what are practically test conditions with expert supervision and that such economy is very difficult to obtain in commercial service.

The relative economy of simple and compound engines has been so exhaustively discussed in years past that only a few words need be said about the application of the latter to isolated plant service. The tendency of the times toward increased efficiency in all industrial enterprises is perhaps in no way better shown than by the enormous increase in the demand for compound engines as compared with that for single-cylinder engines. The isolated plant has felt the advance, and except in those cases where the compound engine is not adapted to the service, where the question of steam economy is a secondary consideration, fuel costs little or nothing, the engine is a reserve or auxiliary power unit, or where all the exhaust steam is required for heating purposes, there is little question about the superiority of the compound. Generally, a saving of from 10 to 35 per cent. in the cost of operation is to be expected, and this, in a short time, will usually pay back the additional investment.

Experience has shown that little extra complication is added by the compound cylinder of the automatic high-speed engine; designs have been so well tried out in practice that the cost of maintenance is almost eliminated as a factor in the choice between the two types. The comparatively small amount of fuel—about 1 per cent.—that is required to raise the steam pressure from the old standard of 80 pounds to 100 or 125 pounds causes the power contributed by the added pressure to be produced at a greatly reduced cost. It is generally safe to figure an increased cost of from 30 to 40 per cent. in comparing compound with simple engines of the same rated horse-power.

Some engineers hold that compound engines should be used only when the load is large and reasonably constant, and when the price of fuel is high. In some cases, the severity of the heating season and its length are important factors. In a vacuum heating system, there is no back pressure, however; with an ordinary gravity system there is no need of over 1 or 2 pounds back pressure, even on the coldest days, if the piping is laid out in ample sizes. Hence, the advantages of compounding are more and more coming to be realized in modern plant designs, and the tendency toward the use of two steam expansions has already become very marked.

In conclusion, every competitive engine should be considered with respect to the quality of workmanship, ease of access for inspection and repairs, neat appearance, positive and absolutely clean lubrication system, ample bearing surface, substantial working parts and liberal design of frame. The ability to give continuous service under heavy duty and to operate economically under the conditions expected in the plant are far more important matters than a few hundred dollars' difference in first cost.

THE SUGGESTION SYSTEM

By H. F. J. Porter

"It is only by labour that thought can be made healthy, and only by thought that labour can be made happy."—Ruskin.

A SUGGESTION BOX AT THE WORKS OF THE NERNST LAMP COMPANY, PITTSBURGH

THE distinguishing feature of what is known as American practice in the mechanic arts and trades is the tendency to specialize. Great trusts composed of aggregations of plants are formed to manufacture some particular commodity. To each of the plants respectively is, in turn, assigned the function of turning out a special line of that commodity. Again these plants are divided into shops, each devoted to producing a special part of the assembled product, and each of the shops is subdivided into departments where certain lines of work are performed.

The general tendency towards specialization was brought about initially by the severity of competition which accompanied the growth of industrial enterprise during the latter half of the last century. The refinement to which specialization was carried in the shops where men and women learned and subsequently devoted their entire time to one operation, was made possible by the ready adaptability of trade conditions to meet new requirements, and the realization by experts in management that the same principle of competition which had forced them to reduce their prices would work both ways and cause a reduction of prices of labour by securing closer competition between the individuals in their employ.

This was a recognition of the working of the law of cause and effect, but it was not accompanied by an understanding of the real underlying force at work which is the foundation of all competition. This force is one with that which through all the ages has irresistibly made for progress. It evinces itself in man through his desire to excel his fellows. It works inerrantly whether applied to nations, communities, to organizations, or to persons.

I say that there was not a full understanding of the principle that the managers were introducing, otherwise they would not have stopped short half-way in its application. I mean that they did not realize the fact that by restricting the individual to a specialty in competition with his fellows, the opportunity was opened to him to become an expert, and

therefore, as he was not accorded his proper status, his full efficiency could not be, and never was, made available.

An expert is a person who is better acquainted with and more skilled in his specialty than others. No matter how small or insignificant apparently the operation may be, if it is specialized, the person who performs it becomes an expert.

Now an expert who has the temerity to assume the title and hang out his sign indicating his availability for consultation regarding his specialty can ordinarily obtain a fair price for his opinion. How did the experts in the shops fare in this regard? Were their opinions ever sought, or, if given, were they heeded? Very seldom.

Why? Generally speaking because managers had not divested themselves of the customs which had come to them by tradition and heredity. The conditions governing the patriarchal method of management which obtained when the owner of the shop was an all-round mechanic and his workmen were less skilled and experienced no longer existed, but the modern manager was unwilling to relinquish the reputation of knowing it all which still adhered to the title, and he lost as a consequence the advantages he could have derived from his more experienced possessions, a loss which in some trades has been inestimable and irretrievable.

That these animadversions are not mere opinions there may be cited facts, based on the aphorism that "the exception proves the rule," which show that when the expert knowledge which is possessed by the employees of industrial enterprises is recognized and made available, methods and processes are thereby simplified and cheapened, the product is improved and both employee and employer are gainers by the spirit of industrial confidence which is engendered.

The writer has been a student of methods of management for the past

THE SUGGESTION BOX AT THE WORKS OF THE NATIONAL CASH REGISTER CO., DAYTON, OHIO, U. S. A.

IN THE WOMAN'S DEPARTMENT OF THE NATIONAL CASH REGISTER CO.

twenty-five years, at times as an interested participant and at others as the principal in establishing systems of organization. In some of the concerns with which he has been associated he has seen evinced on the part of the management, and in this title is included the superintendent and sometimes the foreman, a spirit of confidence that they were superiors in general knowledge, all-round experience, and skill to their respective subordinates, and this attitude of superiority was carried to such an extreme that the two classes were outside of the pale of each other's speaking acquaintanceship except in working hours. In these concerns, however, it sometimes happened that a good idea from some expert workman would emanate in such a manner as to preclude the usual assumption of the foreman or superintendent as its author. On such occasions the greatest uneasiness was displayed on the part of the management as to whether the originator should be recompensed or not.

The idea prevailed, and very strongly, that it was the privilege to be employed by them and that any ideas developed on the part of anyone within the organization belonged to the management by right. This policy of getting something for nothing usually reacted on the possessor and very few ideas developed under it.

There have been other concerns, however, with whom the writer, in common with other employees, considers it a privilege to have been connected, where workmen were engaged because they were experts in their specialties. Foremen and superintendents, because they were experts in details of shop management, encouraged the development of ideas on the part of the expert employee. The management, in turn, paid liberally for every idea proposed that could be made available, and rewarded that foreman who succeeded in encourag-

ing his employees to contribute the greatest number of practicable ideas regarding their work.

The method whereby new ideas are encouraged and automatically find a channel leading to an impartial body which estimates their merits and either rejects or recommends them to the management for adoption is called "The Suggestion System." In this system usually small locked boxes are distributed throughout the factory or works and the offices. These boxes are provided with a slit through which communications may be dropped. A little pad with detachable leaves and a carbon sheet inserted are provided at each box so that the suggestion may be written in duplicate and all can be put on the same size of paper for subsequent filing. The duplicate is preserved by the writer for reference. These suggestions must be signed by the writer, as otherwise they are not to be considered. They are collected periodically (daily, weekly or at other stated intervals according to the necessities of the situation) by a confidential clerk who copies them, leaving off the name, and files the original in an envelope large enough to contain any further correspondence that may develop regarding it.

The copy goes forward to a committee composed, according to circumstances, of varying proportions of representatives of the employees and management. Methods of treating the suggestions by the committee must depend upon the conditions governing that body and the nature of the matter in hand.

Generally speaking there are several sources of suggestions, rarely less than two; namely, (1) the factory, and (2) the salesmen, and the suggestions themselves may be limited to certain specific lines of improvement. Those from the factory may be—(a) regarding improvements to and about the factory building or works; (b) improvements in conditions under which work is performed; (c) improvements in factory and office systems, such as record keeping, printed forms, duplication of circulars, advertising, etc.; (d) improvements in methods and processes of manufacture; (e) improvements in design of product; (f) new lines of product.

Suggestions from the salesmen may be in the nature of—(a) improvements in the product rising from criticism by the public; (b) new commercial features; (c) advertising.

A schedule of awards for all suggestions which are available for adoption should be arranged in advance and rules promulgated so that foremen will encourage employees to think for themselves and suggest ideas which they feel will lead to improvement in the various directions scheduled. Sometimes a suggestion will prove entirely impracticable, but the underlying idea will suggest to someone else a modification which will be available and useful. In such a case care must be taken to divide the award so as to give to each author a fair recognition for value received.

So much for the system proper. In order, however, that it may work satisfactorily, right relations have to be established between organization and management, between employee and employer, so that a spirit of mutual confidence exists; otherwise all efforts to secure satisfactory results become abortive.

The present tendency of the times is strongly ethical, and managers generally are evincing an inclination towards establishing relations of more harmonious co-operation than have existed in the past. Wherever such relations have been established, the suggestion system can be readily introduced, and the results will at once become evident in a general improvement throughout the organization. If such relations have not yet been secured, the enterprise is behind the times, and competitors who are more alive to the trend of events will easily, by the adoption of the suggestion system, secure a handicap which

will place them well in the lead, and it is elementary that a stern chase is a long and difficult one.

It is possible that some concerns who have known of the advantages to be derived from the establishment of close relations with their working organization, such as are frequently typified in the press by Krupp in Germany, Cadbury's in England, and the National Cash Register Company in America, are deterred from adopting them from a feeling that to make such radical changes as would be necessary to arrive at the conditions there existing would entail a tremendous upheaval in their organizations and involve an enormous outlay of expense. It should, however, be remembered that the concerns mentioned were once operated on the ordinary basis, and it was because they found that it would pay them better to adopt more logical methods of securing the co-operative effort of their employees that they changed their policy.

It should also be remembered that the change was made more than a quarter of a century ago and that the vastly improved conditions under which these concerns are now operating are merely a testimony of the appreciation of what is due to their employees.

From personal experience the writer can state that such a change can readily be initiated with practically no expenditure of money. In fact, the less money is involved in it, the more firm is the foundation and the more healthful and permanent will be its growth and development. Expenditures can be made as the business improves and circumstances seem to warrant them.

What is necessary is the establishment of cordial relations between the management and the working organization. This usually means a change of attitude from one of autocratic domination on the one side and dogged resistance on the other to one of mutual helpfulness. The thought of the employer must change from "how can I squeeze more money out of my plant?" to "what can I do for my employees that will equip them better to work for me?"

The thought of the employee must change from "how can I force higher wages and shorter hours from the boss?" to "what can I do to improve the business and thus improve my own condition?"

As soon as the management can get the working organization to work with rather than for it, it will have achieved the change of sentiment on both sides, and advance from that time on will be rapid.

In a recent organization of a small manufacturing concern which, by the ordinary methods of management, had under two administrations as often failed to successfully market its product, the entire system was changed without any appreciable attending expense. By the introduction of the suggestion system the product was perfected and its manufacturing cost lessened.

Within a very short time the company arrived at a paying basis, the organization, consisting of 150 hands equally divided as to sex, was nearly doubled, and at the end of the first fiscal year a fair return on capital invested was realized for the first time.

This is only an example of what can be accomplished by the suggestion system coupled with what are known as modern methods of organization and management, which are based on principles ethically sound.

The appeal to man's highest self will invariably be met by a corresponding desire to express itself in action, and an increase in effort will be developed.

Human nature is human nature without any exceptions and must be reckoned with in man's dealings with men. But it cannot be dealt with haphazard, and the better one's understanding of it and tact in treating it, the better will be the outcome of his undertakings.

ACCIDENT-PREVENTING DEVICES IN AMERICA

AN AMERICAN CRITICISM

By George Ethelbert Walsh

INVENTIVE ingenuity is nowhere more apparent than in the field of accident prevention, and at the Patent Office at Washington applications for new devices for safeguarding human life are of almost daily occurrence. In almost every department of industrial and home life, ingenious inventions are made for eliminating the danger element as far as possible, and when one studies a classified list of such devices it would seem as if the risk to limb and body in modern America should be almost insignificant.

But statistics of casualties and deaths do not support this superficial impression. On the contrary, we find that, although the foremost nation of the world in the number of inventions patented for safeguarding life, we stand first among all countries in the number of lives lost through accidents. In railroading, in mining, in manufacturing, and in general building operations, the number of accidents in the United States is annually greater in proportion to the population than in any of the civilised countries of the globe. While in the past few years some slight decrease in the number of accidents in certain departments of work has been accomplished, we are still far from reaching the same level of immunity that has been established in the different European countries.

An attempt to explain this peculiar condition of affairs is not so difficult, for the cause may be summed up in the simple statement that the employment of safety devices is not enforced in this country by law so rigidly as in most of the manufacturing countries of Europe. The inventor of safety devices is too often discouraged in his work through the lack of co-operation of manufacturing companies and of the Government. While we stand first in respect to activity in inventions, we are nearly at the foot in respect to the enforcement of adequate laws for protecting human life.

Thus we see the very peculiar anomaly of life-saving inventions, inventions made and patented in this country, used in foreign countries, but not adopted here, except in a very limited way. A great many American patents for saving human life bring in more money to their owners when the rights are disposed of in Germany or England than when they are disposed of in America. Patent life-saving devices of American design are found in use in the mines of Germany and of Italy, whereas at home they are not generally employed. If they are used here and there, it is usually a matter of favouritism. Unless the manufacturing or transportation companies voluntarily adopt them to protect their employees, they are liable to remain neglected for years.

Comparisons of deaths and accidents in the leading manufacturing countries indicate the results of a policy which fails to unite the manufacturer's interests with those of the inventor. Among the miners alone the number of accidents in this country surpasses those of any similar kind in any country of Continental Europe. For every thousand miners employed in the United States, the average number killed each year is 2.36; in Germany, 1.88; in Belgium, 1.62; in England, 1.58; in Italy, 1.30,

and in France, 0.85 While it is possible that the local conditions of mines and of methods pursued in getting out the ore by improved machinery may partly explain the difference thus indicated, it is impossible to escape the conclusion that lax laws and non-employment of proper safety devices are responsible for a great unnecessary loss of life.

Our railroad accidents show conclusive evidence that all possible efforts are not being put forth to safeguard human life. In the last five years 38,890 people were killed on the railroads of the United States, and 253,823 were injured. To make these statistics seem even more emphatic, it may be stated that the average number of people killed per day for the past five years has been 21, and the number injured per day for the past five years has been 139. Such an appalling list of the maimed and killed employees and patrons of the railroads of a single country makes war seem somewhat tame in comparison. There has been no attempt to analyse these statistics for ascertaining the relative number of avoidable and unavoidable accidents, but some light may be shed on this feature of the subject by investigation made in Germany. There the number of railroad accidents is far less than in this country, but the strict enforcement of rules governing the use of safety appliances has eliminated many dangers that are so apparent in the United States. Nevertheless, out of 15,970 accidents in Germany 53 per cent. were pronounced by investigators as avoidable and needless. On a similar basis, fully 70 per cent. of the accidents on American railroads should be placed in the same class.

A recent comparison of accident cases showed that the number of deaths from accidental causes in the United States was greater than that in all of Europe combined. For every three men killed in Europe by accidents five were sacrificed in this country. In a great many instances, however, the accidents were attributable to causes which cannot legitimately come under the heading of preventable mishaps. Then, too, it is commonly said that the American public would not tolerate many of the restrictions placed upon the railroads in Germany, and that greater freedom of action is preferable to a strict enforcement of rules that hamper travelers. However this may be, the need for more safeguarding of human life in this and other countries is apparent, and the movement in Europe to reduce the death rate among employees should have its counterpart in the United States.

Of the thousands of devices invented to prevent accidents in this country, comparatively few are ever placed upon the market or are brought directly to the attention of the employers of labour. Such devices are the product of individual inventiveness, but through the lack of co-operation of operating companies their usefulness is never really understood. It is also true that scores of the inventions so made are practically of little value. They are too often the product of minds which have not taken into consideration all of the details of the work for which they are invented.

An employer of a large force of men recently remarked that it would take half of his time to investigate the alleged safety devices brought to him. "Some of them," he said, "appear good, but upon trial they fail. Others are such poor things that only a disordered brain could have conceived them." For a time this same employer took special care to examine into a great many of the safety devices offered, and some of them he submitted to his superintendent, but they were eventually shelved for some good cause. The few that were adopted proved unpopular with the men. They objected to using something to protect themselves from accidents which they could prevent by exercising a little caution. "For instance," said he, "there were a great many truckmen employed who had to load and unload heavy barrels. A

number of broken legs each year showed that the work had in it an element of danger. The truckmen were provided with skids equipped with ratchet teeth, which device effectually prevented a barrel from slipping away from them and rolling down. But it was of little use. The truckmen laughed at them, called them toys for children, and went ahead loading and unloading without the skids. They preferred the risk of breaking their legs to using such inventions. Nothing short of a law compelling the men to use the skids would make such an invention of practical value."

An employer of a large number of stone- and marble-cutters had a similar experience with the use of goggles, which were invented for protecting the workmen's eyes from dust and flying pieces of stone. In many parts of Europe it is compulsory to use goggles for this kind of work, but in this country it is purely optional. The stone-cutters mentioned discarded the goggles. They were not used to them, and they were unwilling to change their methods. Yet from this cause alone, an eminent occulist reports, scores of eyes are either ruined or temporarily injured so as to cause a considerable loss in wages to the employees.

It is apparent from these and other similar instances, that the co-operation of employers and employees is essential in order to lessen the death and accident rate by a more general adoption of safety appliances. This, in fact, has been the experience of manufacturers in Europe. Before the present movement was there started to safeguard the lives of employees more thoroughly, it was frankly admitted that the objections offered by workmen to the adoption of new devices would have to be overcome. It was seen that the advantages gained from the use of the best invention could be nullified by the antipathy of the men. Educational methods for the employees were therefore needed fully as much as the co-operation of the manufacturing interests. The establishment of the Museum of Security at Amsterdam, Holland, had this point in view when it arranged its display of safety devices for the public.* While the employer of labour could there study the methods adopted by other manufacturers for protecting the lives of their employees, the workmen could also see examples of what was being done for their welfare. Since the opening of this museum, the workmen and their families are more frequent visitors than are the employers of labour. The educational influences of the museum are thus of the greatest importance.

The movement to establish a similar museum of security in this country through the liberality of large manufacturing interests, has already made good headway, and it is probable that before long a building will be provided for exhibiting and classifying the thousands of inventions devised for safeguarding human life. Such a museum would furnish illustrative material for both workmen and manufacturers. Statistics would furnish valuable data to those interested, and specialised work in the various industries would make it possible for manufacturers to learn at once if there were inventions made to cover any particular field of work. Inventors would also be helped in their work, and this is important, for while some fields are overcrowded with safety devices, others have been almost entirely neglected.

Few men are so well educated in their particular line of work that they could not find something of value to them in such a museum. In other parts of the world safety devices are employed which have never yet been duplicated in the United States, while many of our inventions cover fields of which the manufacturers in Australia or the miners in China or Japan have never heard. The co-operation of industrial and manufacturing leaders

* The exhibits in the Museum of Security at Amsterdam, Holland, together with the institution itself, were illustrated and described by William H. Tolman, Ph.D., in CASSIER'S MAGAZINE of August, 1902.

should not therefore be confined to any one country.

The multiplication of new industries constantly calls for new safety devices. Many of these are the products of men employed in those particular industries, and their usefulness in many cases may not be known outside of perhaps one particular shop. There should be no monopoly of inventions made to safeguard life, and, indeed, no such intention is implied by a company not advertising such devices used by its employees. In a great many cases the inventions are not even patented.

A museum of security should bring together in a classified exhibition the patented and the non-patented appliances for protecting life in all the different departments of human endeavour. Their orderly exhibit would do as much toward educating employees to use them properly as toward inducing employers to adopt them. This has been particularly exemplified in the Amsterdam museum, where practical illustrations of the respective values of the different devices are exhibited. Machinery, with all the safety appliances in place, is in operation during the hours of exhibition, and even dummy workmen are in position to show how the appliances operate. Red paint is used on every moving part of the machinery to indicate danger. Rapidly revolving emery wheels are surrounded by hoods to protect the operators if the wheels should fly to pieces, and buzz-saws are similarly cased in so that no arm or leg can be injured. All belts and shafting are protected by a number of devices to prevent operators getting caught in them. Simple inventions for filtering the air in factories where chemical fumes threaten the lives of workmen, and air-tight helmets for employees in those lines of industries where noxious gases render life uncertain, are exhibited in classified form.

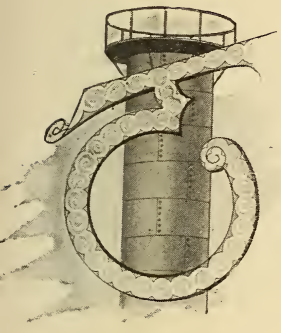
Many new devices not used anywhere find a place in such a museum, —inventions which may in time save the lives of thousands of workmen, but which to-day are not understood or appreciated. A great many manufacturers have visited the Amsterdam museum out of curiosity, and as a result of their observations they have installed safety devices in their factories which add greatly to the health and happiness of their workmen. Not all safety devices are intended to prevent accidents; many of them have even a higher object. By preserving the health of employees in factories where dust or fumes of a poisonous nature slowly undermine their strength, a good is accomplished that is of mutual benefit to employer and employee.

When it is realised that the life and health of every skilled workman represent an asset that a factory cannot afford to ignore, the value of using all possible protective methods for insuring the same will be appreciated. We in this country have been slower to recognise this fact than have the employers of labour in Europe, but efforts are now being made in the right direction. Under the energetic work of the American Institute of Social Service, a movement to cooperate with the Amsterdam Museum of Security has already reached the stage where success is promised. As an inducement to manufacturers and other employers of labour to co-operate in this respect, it has been pointed out that thousands of suits for damages would thereby be saved, and in the end this would more than pay for the endowment and support of the institution.

There are every year in this country thousands of needless accidents in mines, in factories, and on railroads that fill our courts with damage suits aggregating millions of dollars. While some of these suits are dismissed, the cost of defending them in the courts is an important item. It therefore follows that, as a matter of investment, every employer of labour should encourage co-operation to increase the use of safety devices in factory, shop, and mine.

IRON ORE BRIQUETTES FOR THE BLAST FURNACE

By Henry Louis, M.A.



THE idea of briquetting pulverulent iron ores in a form sufficiently compact to enable them to be used conveniently in the blast furnace is far from being novel, and the process itself has been in operation for over twenty years. It is only quite recently, however, that it has been carried out on a scale of any magnitude, whilst indications are not wanting that its importance is likely to increase in the near future.

Like practically every other development in modern siderurgy the origin, or at any rate the need, for this process may be traced to Bessemer's great invention. Before his time practically the only criterion of the value of an iron ore lay in its richness in iron, independent of its purity. When the production of mild steel became one of the main objects of iron manufacture, the purity of an ore in the sense of its freedom from noxious elements,—sulphur and phosphorus,—assumed the great importance that it has to-day, and ores that were pure as well as rich came into demand. These ores being far less abundant than the more impure varieties, all sources whence such ores, called Bessemer or hematite ores, could be obtained were laid under contribution.

It seems to have occurred almost simultaneously to several workers that the residues left after burning pyrites for sulphuric acid making, especially the finely ground residues from cupriferous pyrites from which the copper had been extracted by the method originally devised by Longmaid, but first carried out on a commercially successful scale by Henderson about 1870, were well adapted for use as Bessemer ores. These residues, known as "Blue Billy," or "purple ore," were used at first for fettling puddling furnaces, and were probably also added in small quantities to the charges of some blast furnaces. It is said that Longmaid first suggested the briquetting of this purple ore, and in 1872 Mellet and Scholefield patented the use of silicate of soda for this purpose.

The manufacture of purple ore briquettes practically commenced in Great Britain about 1885, the Tharsis Company, the Bede Company, Messrs. Mason & Barry and others all engaging in it about the same time, and from that date the production of purple ore briquettes has gone on steadily increasing, both in Great Britain and on the Continent.

The production of briquettes from other materials is of much more recent origin, little having been done before the commencement of the present century. All the materials available for the manufacture of briquettes for the blast furnace may be divided into two classes, namely, crude fine ores, and ores that have undergone some process of concentration or purification, which must naturally be preceded by fine crushing.

Generally speaking, it is only high-class, rich and pure ores that happen to occur naturally in a state of fine division, that come in the former class, because it is only such ores that can stand the cost of the briquetting operation.

Such ores occur in many parts

FIG 1.—THE ORE BRIQUETTE KILNS OF THE UNITED ALKALI COMPANY AT ST. HELENS

of the world, and are usually brown hematites, such as are mined in various parts of Spain and Algeria. No better practical example can be quoted than the briquetting of the soft ores from the Alquife mines in Almeria, Spain, at the works of the Coltness Iron Company, Limited, at Newmains, Lanarkshire, which will be referred to in greater detail subsequently.

It might have been expected that the United States would have been the pioneers in this class of operations, seeing how great have been the difficulties encountered in attempting the use of soft, pure ores of the Mesabi range. The use of these ores has been, and is still, attended with numerous inconveniences, such as slips and irregular working, hanging of the charge, etc., whilst at one time explosions in the upper part of the furnace were disastrously common, and are perhaps not even yet altogether a thing of the past.

American ironmasters have attempted to minimize and put up with these troubles instead of seeking for the radical cure that briquetting would have afforded, and have in this respect, at any rate, shown themselves less progressive than their British fellow-workers. It is true that in a few cases they have attempted to save the very heavy loss of iron in the flue dust produced by Besabi ore, by briquetting this flue dust, and charging the briquettes thus made back into the furnace; but the briquetting of the crude fine ore, which would form the radical cure for this evil also, has not been resorted to.

The briquetting of ores that have been artificially comminuted, of which purple ore is a fairly typical example, depends upon rather more complex considerations; it is always preceded by some process of concentration or of purification, the object of which is either the enriching of the ore by removing a portion of its earthy gangue, or the purification of the ore by removing injurious impurities. It is, of course, by no means unusual to find that both these objects are being attained to a greater or lesser degree simultaneously by the same set of operations.

Perhaps the best example of concentration that can be quoted is Edison's well-known series of experiments on a working scale at Ogden, N. J. The crude material there con-

sisted of a gneissose rock containing about 25 per cent. of metallic iron in the form of magnetite. This rock was quarried in large masses, loaded on to cars by steam shovels, crushed by huge, specially devised rolls, which were fully described in a recent paper read before the Institution of Mining and Metallurgy by Messrs. Simpkin and Ballantyne, magnetically concentrated, and the resulting concentrate briquetted. These briquettes were smelted with entire success, and even constituted for a few days the sole burden of one of the blast furnaces at the Crane works, at Catasauqua, Pa. This was in the year 1897, and was the first instance known to the writer in which a blast furnace was run solely on briquettes, forming one more example of Edison's wonderful achievements as a pioneer.

Technically, the various operations at Ogden were a complete success, although they were a commercial failure; the cost of recovering so small a proportion of iron from hard rock proved to be greater than the value of the ore produced. Purple ore may be regarded as an example of purification, seeing that cupriferous pyrites, which is obviously useless as an iron ore, is so far freed from its sulphur and copper contents as to make a high-class iron ore. It is, of course, true that the production of such ore is only secondary to the main objects of the treatment which is really directed to the utilization of the sulphur and copper contained in the pyrites.

Another example is the crushing, concentrating and briquetting of sulphury magnetite at Herrang, recently described by the writer in a communication to the Iron and Steel Institute. Here a certain amount of enrichment also takes place, but the main object of the process is the removal of the high percentages of sulphur that made the crude ore useless. A practically identical process, although on a smaller scale, has been in operation for more than three years at Bredsjo, in Sweden, where, however, only certain of the ores are thus treated, the burden of the furnace consisting of a mixture of crude ore and briquettes. In America the same process is about to be applied to the low-grade sulphury magnetite of the Cornwall ore banks at Lebanon, Pa.

Ores consisting essentially, as many do, of practically pure magnetite mechanically mixed with gangue or with impurities such as apatite or pyrites, are obviously well suited to the processes of magnetic concentration, by which they can be either enriched or purified, or both together. The advantages of purification are sufficiently obvious, seeing that impurities can be removed mechanically before smelting that cannot possibly be got rid of in the blast furnace. It is true that when the ultimate object is the manufacture of steel, processes of desulphurization and dephosphorization can be employed, but these add to the cost of steel manufacture.

The importance of producing a pure pig-iron is best gauged by the fact that hematite pig-iron is worth on an average about 57/6 a ton, whilst phosphoric Cleveland pig-iron is just about 10/- a ton cheaper. These figures indicate fairly well how much money may safely be spent upon the mechanical purification of an ore and yet leave a margin of profit.

There is an evident advantage in getting rid of injurious impurity at the earliest possible stage in the manufacture, and it is not astonishing that there should be a growing tendency to apply these methods to ores that are suited to it. Few ores can be mentioned better adapted to them than those of Gellivare, in Northern Sweden, consisting, as they do, of a granular magnetite intermixed with coarsely crystalline apatite, from which the particles of iron ore can readily be freed so as to produce a high-class Bessemer ore from a crude phosphoric ore.

It has been proposed for some time past to apply this process to the small ore and refuse produced at the Gellivare mines, and the project is now on the point of being put into execution.

FIG. 2.—THE SCREENING PLANT, ELEVATOR AND BRIQUETTING HOUSE OF THE COLTNESS IRON CO., LTD., AT NEWMAINS, LANCASHIRE

Even iron ores that are not magnetites may be rendered amenable to this treatment, as all iron ores, even when not magnetites, can be rendered magnetic by simple and inexpensive processes. So apparently unsuitable an ore as Cleveland ironstone is susceptible of improvement by such methods. Thus the writer found in a series of experiments that from poor Cleveland ironstone a concentrate could be obtained containing 44 per cent. of iron and 0.5 per cent. of phosphorous, whilst the tailings contained 26 per cent. of iron and 0.9 per cent. of phosphorus.

The advantages of ore enrichment are less self-evident than those of elimination of impurities, because the former is an operation that is necessarily performed in the blast furnace during the course of smelting, and it becomes, therefore, a question where it can be most cheaply performed. Any gangue in the ore has, of course, to be fluxed in the furnace by the addition of limestone or some other suitable flux; the ingredients have to be combined to form silicates, in doing which heat is absorbed; the resulting silicates have to be fused also at the expense of some heat, and lastly the molten slag flowing from the furnace carries off some more heat, all of which heat has to be generated by the combustion of an expensive fuel, and is wasted as far as the direct object of smelting is concerned.

It is, of course, impossible to work a blast furnace without making slag, but in practice it will not be found that briquettes will cause any inconvenience in this respect, whilst they present the advantages that, owing to their richness, the output of iron from any given furnace will be increased, the consumption of fuel will be diminished, and the escaping gases, owing to the smaller amount of limestone used, will have a higher calorific value. The gases will also carry less flue dust,—a point that the rapidly increasing application of gas engines fed with waste blast furnaces gases is making very important. It remains, therefore, to decide in each case whether the

cost of crushing, concentrating and briquetting an ore is too high a figure to pay for these advantages, and this is a question that admits of no general answer. Each individual case must be considered by itself, on its own merits.

One of the most interesting examples of ore enrichment, combined, however, with a certain amount of purification, is the large installation now being erected at Dunderland, in Norway, where it is proposed to crush, concentrate and briquette vast deposits of low-grade iron ore containing about 45 per cent. of iron. The ore will be quarried, loaded by steam shovels, and crushed in Edison rolls. It will then be concentrated in magnetic concentrators specially devised for this ore by Edison, and particularly interesting because the ore consists not of magnetite only, but of a mixture of specular hematite with magnetite. The former ore is only feebly magnetic, the latter highly so, and the great merit of Edison's magnetic concentrator is that it can deal efficiently with both classes of ore.

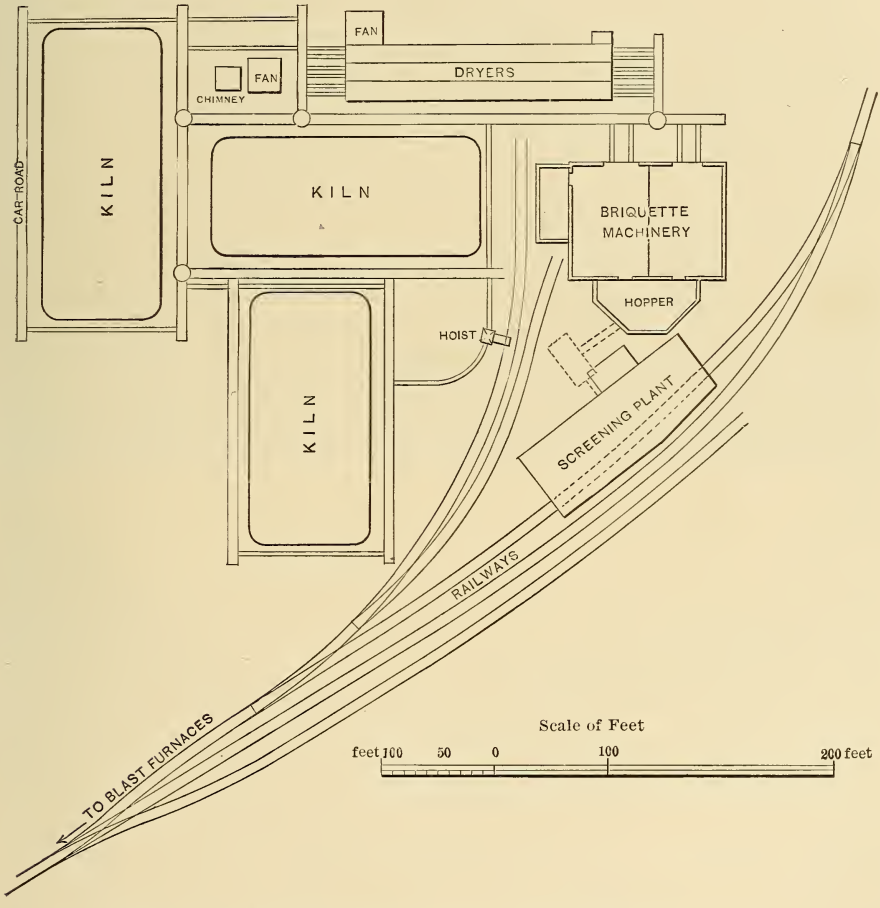


FIG. 3.—PLAN OF THE BRIQUETTING PLANT OF THE COLTNESS IRON CO., LTD.

In whatever way the fine ore may be obtained,—whether naturally fine or artificially made so,—the problem of briquetting the fine ore is essentially the same. Various systems of briquetting have been proposed and pat-

FIG. 4.—THE BRIQUETTE KILNS OF THE COLTNESS IRON CO., LTD.

ented, and some have been put into practical execution. These may be roughly classified as follows:

1.—Processes that depend mainly on an admixture of an organic binder.

2.—Processes using calcareous material, lime, cement, etc., as a binder.

3.—Processes using siliceous material, silicates, clay, etc., as a binder.

4.—Processes using no binder, but depending on firing only.

In the first class a large number of attempts, mostly unsuccessful, have to be recorded, the materials used being chiefly pitch, tar, resin, glucose, starch, coking coal, etc. The briquettes are usually made under a moderate pressure, and generally baked afterwards. The briquettes made by the Edison process at Orange, N. J., were of this type; they were technically excellent, strong and porous, and worked perfectly in the blast furnace. Certain difficulties were met with in their manufacture, but the cost of the binder proved the chief objection, and the process was ultimately abandoned. The writer is not aware that briquettes are at present made anywhere by any of these processes. It is obvious that in dealing with such comparatively low-priced material as iron ores only the most economical processes have any chance of surviving.

Processes of the second class present the obvious advantages that briquettes made by them can in some cases dispense with firing, and that the calcareous material added is useful as a flux; the latter consideration is valid only, however, when the briquettes are made at the ironworks where they are to be used, as no ironmaster would be willing to pay freight on lime from a distant point if he can get that comparatively cheap material nearer home.

The briquetting operations that

have for about ten years been carried on most successfully at the Seaton Carew Iron Works, are best perhaps classified here.

There are two ways, subjects of patents by Mr. Tomlinson, the manager of these works, to whom the writer is indebted for the information. About 700 or 800 tons of briquettes are made weekly by mixing the fine ore with ground blast furnace slag, to which lime may be added if the slag is deficient in this ingredient, moulding into blocks, and allowing the latter to dry in the air, when a strong briquette is produced.

A further quantity of 400 or 500 tons is produced weekly by another method, which consists in mixing the fine ores with flue dust, moulding into briquettes, and burning in an ordinary kiln; about 20 per cent. of flue dust can be worked in with the fine purple ore or other fine ores. Briquettes so made may be smelted even direct in the blast furnace without previous burning. They have proved most satisfactory in practice, making up about one-third of the total burden of the blast furnace. The plant used in making these briquettes consists of an ordinary mortar mill, in which the materials are ground and mixed, and a strongly-built "semi-dry" brick-making press.

Briquettes made with ordinary lime are not being used anywhere in Great Britain, as far as is known to the writer. H. Bumby, in an interesting paper on "The Utilization of Small Ores" (Journal of the West of Scotland Iron & Steel Institute, Vol. IX., 1901-2, p. 147), states that purple ore is briquetted at Le Creusot and Bocau, in France, with an addition of 3 to 6 per cent. of hydraulic lime in brick presses giving a pressure of 70 cwt. per square inch. Mr. Bumby also records the results of a series of experiments which he carried out with briquettes made with lime, in which he subjected them for twelve hours to a temperature of 900 to 1000 degrees F., at a pressure equivalent to what

FIG. 5.—THE BRIQUETTING HOUSE AT HERRANG, SWEDEN

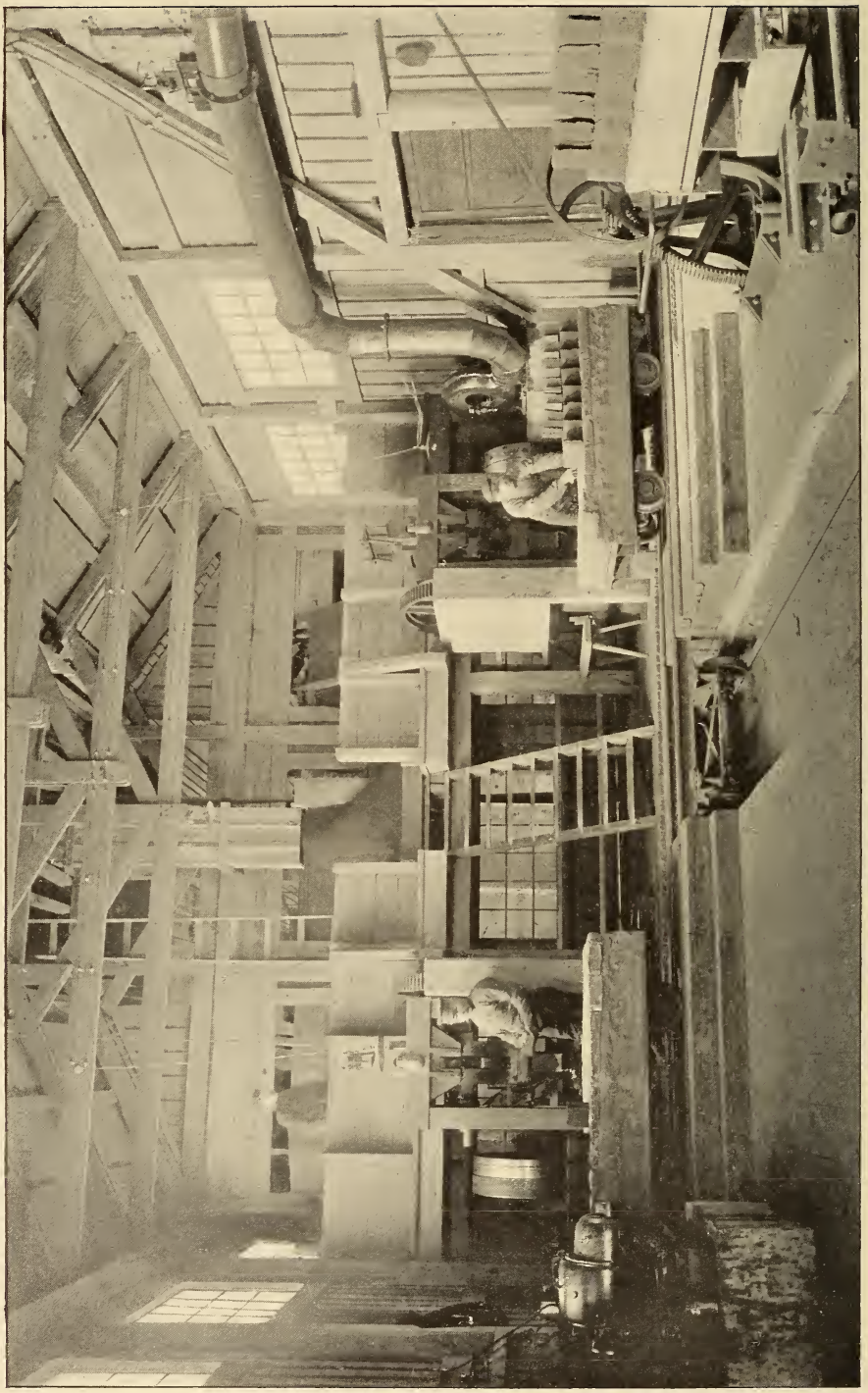


FIG. 6.—THE BRIQUETTING PRESSES AT HERRANG

they would have to stand in the blast furnace, when "all those made with ordinary lime and slag lime and air dried either fell to powder or broke into several pieces, whilst those made with hydraulic lime and steam hardened remained unbroken."

Under the head of the third class comes the proposal already referred to, of using silicate of soda as a binding material. This proposal does not seem to have found any practical application. Various other similar suggestions may be passed over, the only one of these processes of any practical importance being that which depends upon the use of silicate of alumina or clay as a binding material. This method has been in use for a very considerable period for briquetting purple ore, and is still employed in many places. It is used, for example, at the works of the Tharsis Company, on the Tyne, and elsewhere.

The purple ore, removed from the leaching vats in the copper extraction works, is mixed in a pug mill with 4½ to 6 per cent. of ordinary dry clay, which has been ground under edge runners and sufficient water to form a stiff "slurry." This is wheeled in barrows to the drying floor, upon which is placed a grid-like framework, forming a block of moulds without top or bottom. A barrowful of "slurry" is tipped onto the frame, trodden or pressed in by hand, and left until it is dry and firm enough to allow the frame to be lifted, leaving the blocks upon the floor to dry completely. When dry, the blocks are stacked in ordinary Newcastle brick kilns, long and narrow, with two fire-places at either end, in which they are burnt at a full red heat, allowed to cool, and withdrawn. The briquettes thus made are hard and strong; they measure about 9 x 7 x 6 inches. Their composition is shown by the following analysis:—

	Per Cent.
Metallic iron	64.70
Insoluble matter	5.17
Sulphuric acid	0.221
Copper	0.061
Moisture	1.150

The processes that come under the fourth class are the most important economically, and are gradually supplanting the others, as they offer the obvious advantages that they produce a richer briquette whilst no cost is incurred for binding material. They depend upon the fact that both peroxide and magnetic oxide of iron soften and frit at a temperature which, according to the writer's experiments, is about 1200 degrees or 1300 degrees C.

This is the method employed by the United Alkali Company, Limited, at their works in Lancashire, where about 80,000 tons of briquettes are produced annually. The greater portion of this output, however, is consumed by open-hearth steel makers, and not in blast furnaces, so that its consideration is not altogether within the scope of the present article. The method employed consists in pugging the ore, moulding by hand, drying and burning in brick kilns. A view of one of the brick kilns is shown in Fig. 1.

The superiority of briquettes made without any admixture over those made from the same material with an admixture of clay is well illustrated by comparing analyses of the latter with that of the former already given. The following are three analyses of the United Alkali Company's briquettes, obtained from widely different sources, and showing incidentally the uniformity of the material:—

	I. Per Cent.	II. Per Cent.	III. Per Cent.
Ferric Oxide	96.42	94.86	96.31
Alumina	0.84	....	....
Silica	2.02	1.70	1.60
Lime	0.16	....	....
Soda	0.01	....	....
Chlorine	0.02	....	....
Phosphoric Acid	nil	0.01	....
Sulphuric Acid	....	0.10	0.207
Sulphur	0.08	....	trace
Copper Oxide	0.11	....	0.08
Lead Oxide	0.29	....	....
Moisture	0.09	0.06	1.15
Soluble Salts	....	3.27	....
	100.04	100.00	....
Metallic Iron	67.50	66.40	67.42

Briquettes made in this way have been used in blast furnaces at Barrow and at Dowlais, and appear to work well, but in both cases they formed so small a proportion of the total burden that

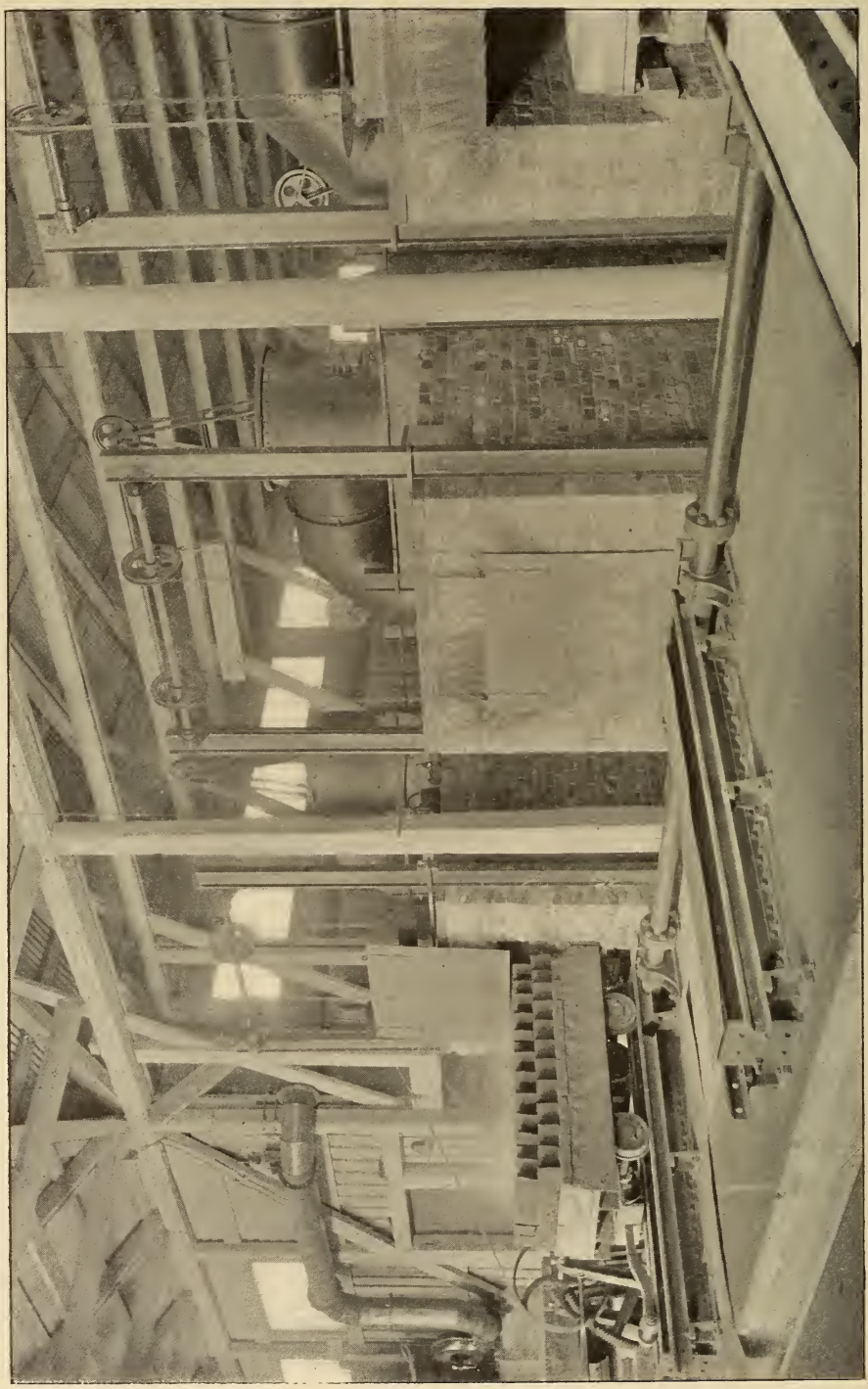


FIG. 7.—THE BRIQUETTINGS FURNACES AT HERRANG

no definite opinion could be expressed as to any advantages or disadvantages attending their use.

Perhaps the most complete installation in Great Britain of briquetting plant solely for blast furnace purposes is that at the Newmains works of the Coltness Iron Company, Limited, designed by Robert Russell. The object of this plant, as already stated, is to briquette the soft brown hematite got from the Alquife mines in Almeria. This ore is chemically good and pure, but makes a large amount of fines, which are a disadvantage in any blast furnace, but are particularly objectionable when the fuel used is raw coal, as is the case at Newmains.

A plan of the briquetting plant is given in Fig. 3. The ore is brought into the works by rail; the wagons are tipped direct on to $1\frac{1}{4}$ inch jigging screens, the under-size being screened further on $\frac{1}{4}$-inch screens, and the over-size from each is smelted direct in the blast furnace.

The under-size, constituting about one-third of the whole, is then briquetted. It is elevated, the elevator being well shown in the outside view of the plant, Fig. 2, and drops into a storage bin holding about 1600 tons. Thence it passes to four edge roller mills of the ordinary type, where it is ground fine and mixed with water. The "slurry" is conveyed to the pug mills of two presses working on the double-pressure lever principle, built by Messrs. Yeadon, Son & Co., of Leeds.

The briquettes measure about 10 x 8 x 6 inches and weigh 37 to 38 pounds raw, 32 to 33 pounds after drying, and 29 to 30 pounds after burning. The presses work at the rate of about fourteen briquettes per minute, the two together making about 6000 briquettes per day of nine hours, though they have made over 7000 in the same time. The briquettes, when they leave the press, are too tender to bear more than their own weight; hence they are lifted carefully on strips of flat iron and placed on cars fitted with a rigid framework so that each briquette occupies a separate compartment. Each such car holds 126 briquettes.

The loaded cars are pushed by hand into one of three drying tunnels, about 120 feet long, through which the waste gases from the kilns are drawn by means of fans, the gases entering these tunnels at about 300 degrees F. The loaded cars remain in the drying tunnels over night, and in the morning the briquettes are dry and firm enough to stand piling in the kilns. The cars are run by hand to the kilns. These are gas-fired Hoffman kilns, built in blocks of twelve in two rows back to back with a flue between them. There are three such blocks, or thirty-six kilns in all, each kiln chamber holding about 6500 briquettes.

The kilns are fired with the waste gas for the blast furnaces, this being here of most excellent quality and produced in such large quantity that the whole of it cannot be profitably employed at the works. The gas is put on very gently for the first twelve hours in order to get rid of all the moisture, otherwise the rapid evolution of steam would split the briquette; then more strongly for another twenty-four hours, and kept on for forty-eight hours more. The kiln is then allowed to cool and the burnt briquettes are finally removed by hand, the time occupied from charging to emptying the kiln being fourteen to fifteen days.

The process is thus a very simple one and the briquettes produced are quite satisfactory. Some difficulty is found in properly regulating the heat, the briquettes in the lower part of the kiln being sometimes clinkered whilst those in the upper part may not be burnt quite enough. This and the large amount of hand-labour required are the only objections to this method of making briquettes.

The use of these briquettes has been found to be of the greatest advantage in the working of the blast

furnaces, the output from the same furnaces having been increased by 20 to 25 per cent. and the running being more regular. In consequence it has been decided to produce briquettes on a large scale at the Alquife mines themselves, by which means the payment of freight on about 10 per cent. of water, which is an essential constituent of brown hematite ores of this description, will be avoided. The principle of the process will remain the same, but it will be carried out in a different manner. The Grondal furnace, which will be described next, will be used for burning the briquettes, as a considerable economy both in fuel and labour will result from its adoption.

The Grondal furnace for burning briquettes was fully described in a paper on "The Manufacture of Pig Iron from Briquettes at Herrang," communicated last year by the writer to the Iron & Steel Institute. It has also been repeatedly described in Swedish technical literature, the most complete account being given in a paper by Tord Magnuson in the "Jernkontorets Annaler" for 1902, which is fully illustrated. It consists of a long tunnel-shaped furnace about 160 feet in length and about 4 feet wide inside. The briquettes, which measure about 6 x 6 x 3 inches, are piled in two or three layers on top of a massive iron car covered with firebrick. The loaded car is then pushed by machinery into the furnace, a carload of burnt briquettes being simultaneously forced out from the opposite end of the furnace.

The sides of the cars are fitted with deep flanges projecting downwards into troughs running along either side of the inner furnace walls, and are kept filled with sand, thus forming an air-tight joint, whilst successive cars also fit air-tight against one another. The air space below the cars is thus entirely closed off from the furnace chamber above the cars. About 60 feet from the charging end of the furnace the arch is made somewhat higher, forming a combustion chamber about 35 feet in length. The flue leading to the stack is just above the charging doors, the doors at both the charging and discharging ends fitting air-tight.

Gas is admitted to the combustion chamber through a flue from a gas producer of any desired type. The air needed for combustion is admitted below the cars, near the charging end, and travels along in the same direction as that in which the cars move until it rises up beyond the last car. Thence it travels over the cars in the opposite direction until it reaches the combustion chamber. This air cools the axles, wheels, and bearings of the cars in the first portion of its travel, and then, meeting the burnt briquettes, cools these so that they leave the furnace, in normal working, at a temperature of about 150 degrees C. The air thus reaches the combustion chamber strongly heated. The products of combustion pass over the cars carrying the green briquettes, which are in this way thoroughly dried, whilst the gases are so far cooled that they reach the stack at a temperature of only about 150 degrees C.

The furnace thus works very economically, the consumption of coal in the gas-producers (when coal is used as fuel) being under 5 per cent. of the weight of the briquettes. In regular work one car carrying about 15 cwt. of briquettes, is drawn, and one is charged every half-hour; and as the furnace will take twenty-four cars, the time occupied by the passage of a car through the furnace is twelve hours.

It may be mentioned that the rate of working at Herrang is kept slow because the ore contains a small amount of sulphur which has to be got rid of, this elimination being effected completely during the process of briquetting. There are three such tunnel furnaces and two ordinary drop presses, the total output having been at times well over 1000 tons a week. The briquettes produced are hard, strong, and yet very

porous, so as to work perfectly in the blast furnace. The blast-furnace plant at Herrang has now been running steadily and successfully for over a year on briquettes alone, this being the only instance, as far as is known to the writer, where blast furnaces have been run exclusively on briquettes in regular work. The fuel consumption in the blast furnace is abnormally low, being under 14 cwt. of charcoal to the ton of pig-iron.

This method of manufacturing briquettes was first worked out by the inventor at Pitkaranta, in Finland, but seems to have been discontinued there when Mr. Grondal came to Sweden. The Herrang plant has been in full work for over a year, and a similar plant has been going at Bredsjo even for a longer time with excellent results. Similar plants are in contemplation or under construction at Sandviken, Guldsmedshyttan, Sprakla, and Lulea. A plant has been completed at Helsingborg for briquetting the purple ore produced at the large wet copper extraction works at that place, and, as already stated, a large plant is about to be erected at Alquife, Spain. Another large plant has been commenced at Dunderland in Norway, and it is also intended to erect Grondal furnaces at Cornwall, Pennsylvania, U. S. A.

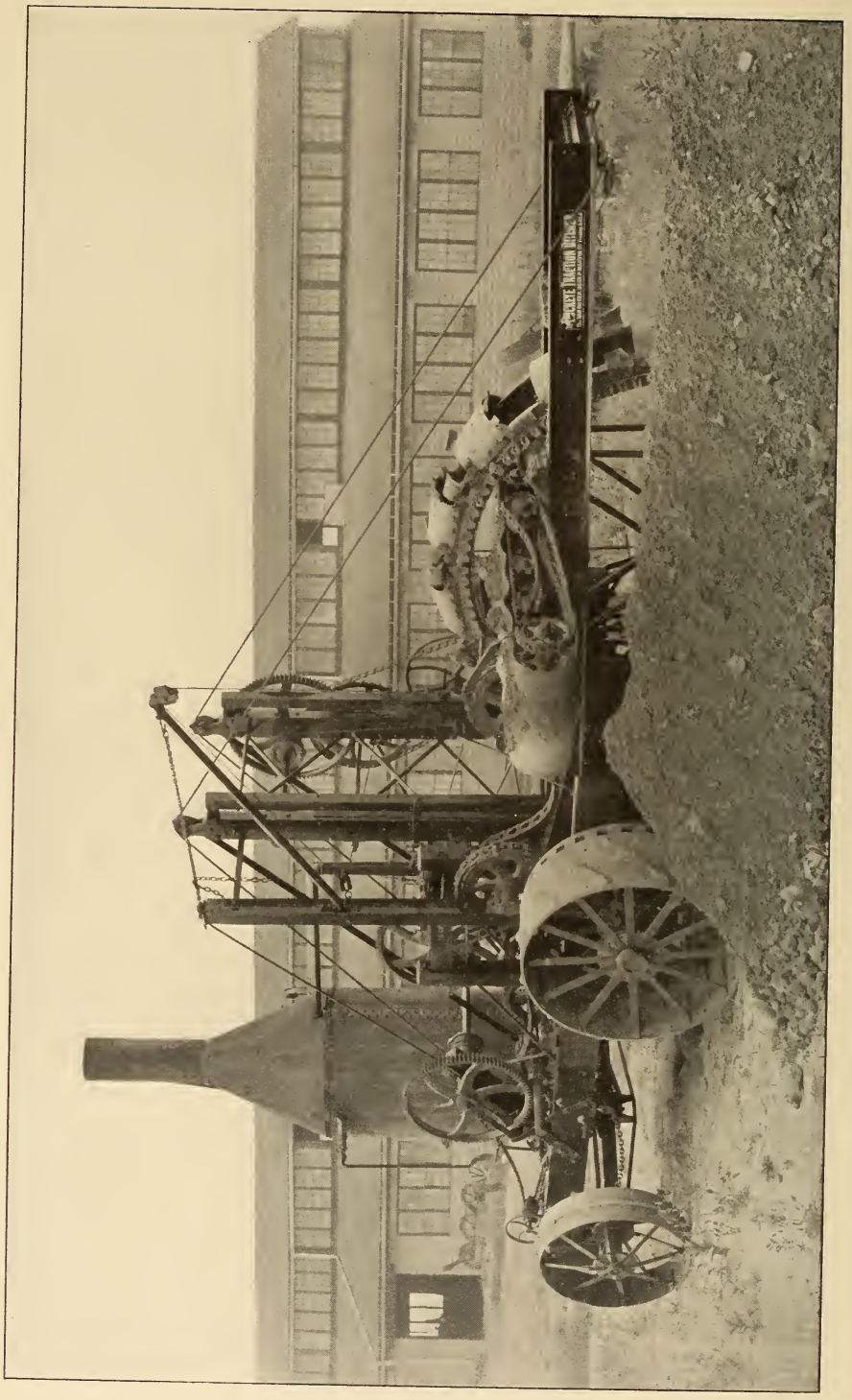
It is obvious that the briquetting of iron ores has long since passed the experimental stage, and that the smelting of briquettes in the blast furnace is also a proved economic and practical success. There is no reason to doubt that this method of dealing with finely divided iron ores, whether artificially or naturally comminuted, will be further extended in the near future. By its means such comparatively low-priced material as purple ore or pyrites residues can be converted into high-class iron ores, and seeing that Great Britain imports annually about 750,000 tons of pyrites, this one item alone is of considerable importance. Furthermore, cheap methods of crushing and concentration, combined with briquetting, will make it possible to smelt with advantage many an iron ore too poor to treat directly in the blast furnace, and the future alone will show how far the mechanical elimination of impurities from iron ores can be carried profitably. Technically, the problem is solved, but its economic limits yet remain to be defined.

A NEW FORM OF EXCAVATING MACHINE

By D. A. Willey

THE ordinary traction engine has been utilised in a variety of ways, especially in connection with agriculture. Recently, in the United States, a form of traction engine has been combined with excavating apparatus, which is of remarkable capacity, considering its compactness and the amount of power required.

The Buckeye excavator, as it is termed, made by the Van Buren, Heck & Marvin Co., of Findlay, Ohio, is designed in several forms, the smaller size being utilized principally for digging small trenches such as are made for sewer pipe, water pipe and other conduits, but some of the contractor's machines as they are termed will cut a trench 12 feet deep and 54 inches wide without the employment of manual labour, except where a stone or other obstruction is encountered too large for the buckets to remove.



A NEW FORM OF EXCAVATING MACHINE MADE BY THE VAN BUREN, HECK & MARVIN CO., FINDLAY, OHIO, U. S. A.

As the illustrations show, the excavator is attached to the rear of the truck supporting the engine. It may be needless to say that it is adjustable, so that it can be raised sufficiently above the surface to be transported from place to place, when the power of the engine itself can be used entirely for this purpose. The wheels on which the tractor rests are provided with tires of varying widths according to the conditions. Where the surface is rough, tires of extra width are employed, but in all cases the surface of the front tires is provided with metal cleats, which aid in furnishing traction.

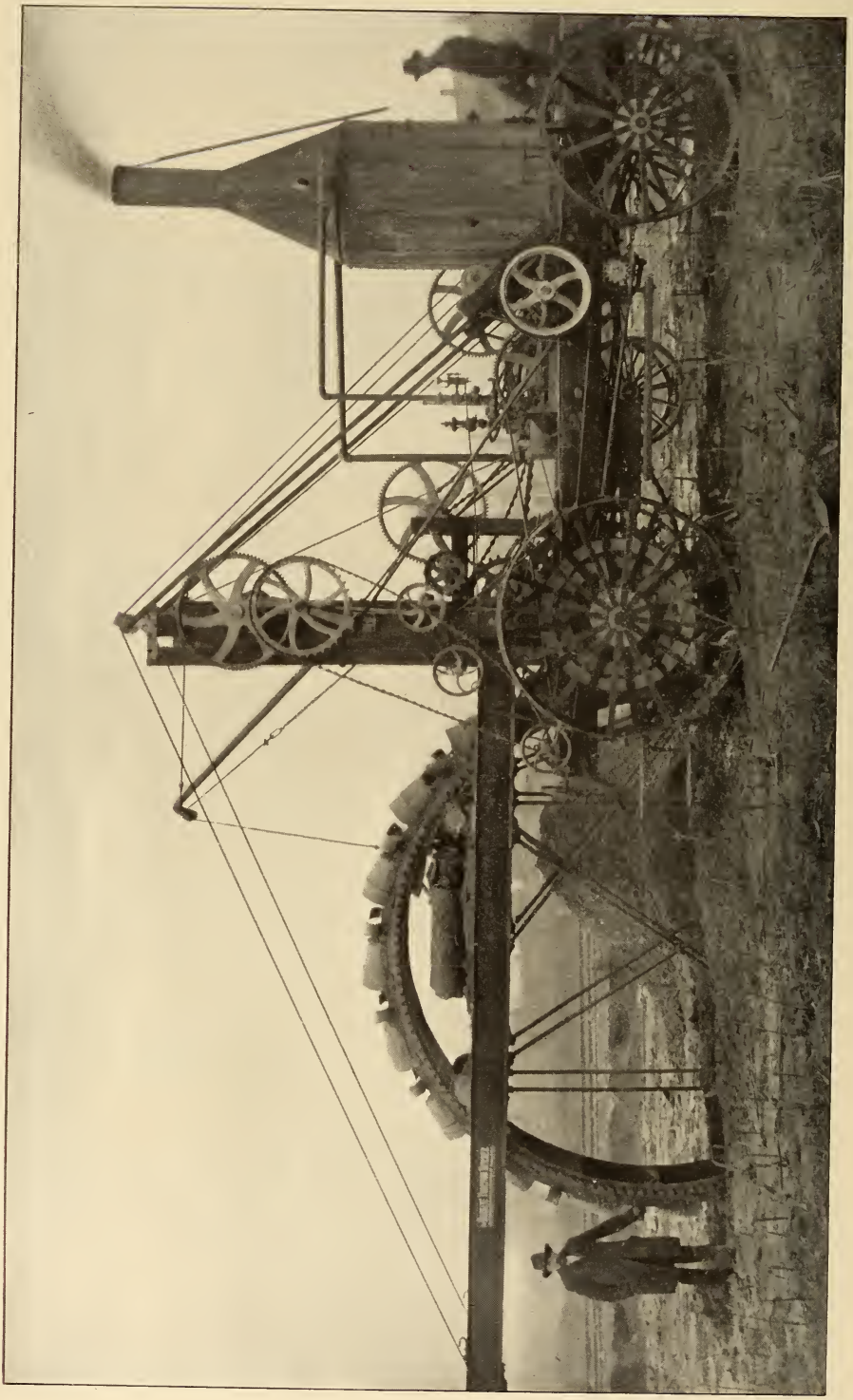
The excavating part of the outfit is practically a cutting wheel, as the trench is made by cutting away the material with revolving knives, and removing it by means of scoops or buckets set in the rim. This rim is divided into two parts, being equal to the width of the excavation to be made. The framework is reinforced by means of steel rods attached to the inner surface, and extending across in the form of the letter X. The buckets themselves are made of heavy steel plates shaped to an edge. Directly in front of each are set two semi-circular cutters or knives. On the smaller machines these are made from stock $\frac{1}{4}$-inch thick, and on the contractor's machines from half-inch steel. The latter type is also provided with buckets to which are attached tools for cutting away roots of trees and other obstacles. In fact they are toothed like dredge buckets used in heavy work, the "rooters" being dressed to a chisel point and specially tempered for the service for which they are intended.

The excavating wheel, as it may be termed, is suspended between two steel girders which move up and down in an upright framework. Besides this motion, however, the girders are adjustable so that they can be raised and lowered from the outer end, by means of steel cables passing through pulleys, fastened in the top of the framework, and leading down over a drum which is revolved by the engine. The wheel can be readily adjusted to the excavation, being automatically lowered as the trench is deepened. The cables are utilised when it is desired to hoist the apparatus clear of the surface.

In operating the dredge, it is moved forward at a speed slow enough to allow the cut to be made level in the formation, the excavating wheel revolving towards the engine. The earth can be removed for a stretch of a hundred feet or any desired distance to a certain level, then the excavator is lifted from the surface, the engine reversed and backed to the beginning of the cut and another section removed, or the trench can be made to the depth required as the work proceeds.

The driving gears are made entirely of forged or cast steel, but the sprocket chains driving the excavator proper are calculated to be the weakest portion of the machinery, so that in case the excavator strikes a rock or other obstacle which it cannot remove, the chain will part before any of the other mechanism is damaged.

For removing the earth and other material after it has been excavated, an endless apron is employed which is mounted on the girders supporting the excavator in such a position that it is always directly beneath the top buckets. As each bucket moves into the proper position, its contents fall upon the apron, which projects far enough from the side to pile the earth well away from the edge of the ditch. To remove clay or any substance which may adhere to the inside of the bucket, cleaners are used which also operate automatically. These cleaners are plates of steel so shaped that they fit the interior of the bucket. As fast as it is emptied the cleaners pass through it, scraping the inner surface and removing any material which may be left. In the rear of the excavating wheel is placed a metal trough or scoop bolted in front of a framework which rolls upon a wheel. This framework is attached to the girders



ANOTHER VIEW OF THE VAN BUREN, HECK & MARVIN EXCAVATING MACHINE

supporting the excavator by means of an upright beam. The scoop is of the same width as the trench, and is intended to cut off any inequalities which may have been left by the cutters—in short, to grade the bottom of the excavation. It is so adjusted that the material it takes up falls into the buckets as they are raised, and its contents are conveyed from the excavation in this manner.

The speed of the excavators of course varies according to the character of the work. In a formation where there is but little stone, a trench 3 feet in depth can be made at a rate of 3 linear feet per minute. Some of the contractor's machines however have made a record of 12 feet of excavation at a speed of $2\frac{1}{2}$ linear feet per minute. One man and a helper constitute all the attendance required, except the man and team needed to haul fuel and water. An idea of the size of the largest machines can be formed from the statement that a 54-inch excavator is 53 feet in length in all, with a width of 12 feet.

INSPECTING ELECTRIC PLANTS FOR FIRE RISK

By George L. Clark

THE reduction of fire hazard is an object of never-failing importance in modern industrial life, and although the day of perfect protection from fire risks is still far off, the increasing interest in the subject is encouraging; in fact, so much valuable information has been printed concerning the prevention of fire that, as far as electric plants are concerned, there would seem to be little excuse for the occurrence of a serious fire upon the premises of any progressive railway, lighting, signaling or power company.

Fires do occur, however, in spite of careful installation of apparatus and wiring. No matter how closely the plant's construction conforms to the accepted standard of the fire underwriters, unless these requirements are maintained, the door is open for trouble to enter. Inspection is consequently the key to the problem, presuming that we have a proper installation in the first place. Inspection is generally effected by the insurance representative at long and infrequent intervals, and by the employees of the company concerned, with more or less regularity and thoroughness, according to the management's ideas of the importance of the matter.

Since the bulk of the actual responsibility falls upon the operating company itself, it is important that the work of inspection be thoroughly accomplished, and at regular intervals. Plainly printed instructions stating how to prevent fires and what to do in case they occur, are valuable, but unless the rules are enforced, they are worse than useless.

On the principle that "everyone's business is no one's business," one or more specified employees in every plant should be given the regular duty of inspecting the premises with an eye to every conceivable cause of fire, and in the vast majority of cases such employee should have the authority to enforce the rules and the obligation to report periodically upon

the existing conditions. If the work of inspection is done in a hap-hazard fashion, the intervals between successive examinations of the premises are pretty certain to grow longer and longer, until the printed precautions become little more than dead-letter laws.

An inspection of an electric plant, whether it be a power station, substation or car house, telephone exchange, or other installation, is something more than a five minutes' task if properly done. Many times an inspection fails in its intended purpose simply because the employee charged with the duty does not know what to look for. A glance or two around the premises reveals a few fire extinguishers solemnly occupying their dusty posts; the wiring looks neat and secure; the motor in the corner of the wood-working shop may be operating within three feet of a pile of sawdust, but there is no sign of sparking at the commutator; two or three seedy coils of hose are laid up on convenient shelves alongside a row of dull red half-full water buckets, and so the inspection is complete and another report is stamped approved by the superintendent's stenographer and consigned to the oblivion of the files.

A thorough inspection of a plant with the fire risk in mind is likely to occupy considerably more than a day in the case of large installations, and well towards half a day in even very small plants. It involves the expression of an opinion as to the general condition of the property, the number of fire buckets, and whether such buckets are filled, painted bright red, and in their proper places, or only partly filled, dull in appearance, out of place, and used for other purposes. The question of loose waste seen lying about outside approved metal cans, the adequacy of such cans to take care of all the waste, the accumulation of dirt, rubbish and shavings outside the provided receptacles, the storage of gasoline, oil, and grease, in or outside the building, the condition and number of hydrants and hose as determined by test, and the condition of store rooms and sheds all are important factors in the problem of protection.

The cleanliness of the premises as a whole, the condition of steam pipes and flues with regard to adjacent wooden floors or partitions, the disposal of ashes, storage of coal and wood, condition of stoves and pipes, cleanliness of boiler tops, contact of insulated wires with metal or woodwork, with particular reference to lamp cord, the loosening of wires, obstruction of lights, use of matches, gas and candles, condition of employees' clothes, closets, toilet rooms and suspension of clothing in lockers must all be considered in making a thorough examination. Further, the inspector should keep an eye open as to the leaving of windows and doors open in lofts and storage places, the provision of sand buckets with scoops, and woolen or asbestos blankets in readiness for instant use in emergency, the conditions of doors, windows, and skylights fitted with wired glass, status of metal shutters, water tanks, pumps, self-closing doors, extinguishers, valves and alarm systems.

Half-hearted measures in the matter of inspection furnish little protection. The cost of proper inspection is insignificant in proportion to its potential value. It is safe to say that less than ten dollars a month will be required to properly inspect any but the largest plants, giving a fortnightly examination of the detailed features outlined. In view of the fact that the reasonable protection of a plant can be accomplished at a comparatively small expense for apparatus, there is no valid excuse for failure to provide the simple remedies of sand pails, blankets and extinguishers in every installation. Often the external conditions are of graver danger than anything inside a plant, and they should never be slighted. The long interruption of service and resulting heavy loss in

public good will and in revenue which follow a disastrous fire are arguments enough for the closest study of the conditions in each particular plant.

As every plant differs in its conditions from every other one, the question of fire risk must in final detail be solved in the manner of a special problem for each plant examined. Electricity is in countless instances made the scapegoat in regard to the cause of mysterious fires by the newspapers and the none too discriminating public, and it rests with the electrical fraternity everywhere to refute these often unjust charges by seeing to it that the installations in its charge are as free from such casualties as human foresight can insure.

Current Topics

Motor Boats, driven by electric or petrol motors, and electric cars, on overhead and underground railways, have developed a new use for compressed air, namely, the blowing of air whistles. For the boats the need of a whistle of some kind was almost imperative, and the excellent service which the compressed air whistle gave in connection with them prompted its adoption on the cars, and is likely to be followed by a still wider extension of it in other directions. Automobile horns, for example, sounded by compressed air, are among the latest adaptations, and still others are likely to follow. The whistles are blown by air from a tank supplied either by a power pump or the equipment may be an independent one, with a hand-operated tank pump. In either case, the whistles are made in many different sizes, following the general style of steam whistles.

In order to afford some idea of the enormous energies which have to be dealt with in the discharge of modern ordnance, Mr. R. A. Hadfield, in his recent presidential address before the Iron & Steel Institute, mentioned that a 12-inch breech-loading gun has been fired with a muzzle velocity of close upon 2700 foot-seconds. This means a striking energy of 42,220 foot-tons. The projectile, if uncapped, would be capable of perforating 44 inches of wrought iron, 34 inches of mild steel, or 19 inches of Krupp-cemented armour; if a capped projectile were used, about

23 inches of Krupp-cemented armour would be pierced. As may be imagined, the inner tubes of guns, at such velocities, are soon worn out; in fact, in larger caliber guns an improved steel for these inner tubes is a matter much to be desired.

LOW-TEMPERATURE experiments with alloys and metals, according to Mr. Hadfield, in his address above mentioned, have shown that at —182 degrees C. pure iron has its tenacity more than doubled; its well-known ductility falls very low; and its magnetic properties remain almost the same as at higher temperatures. This represents the general behaviour of all alloys, excepting those containing nickel, which are less affected as regards loss of ductility, while an iron alloy containing 5 per cent. of manganese and 25 per cent. of nickel has its extraordinary ductility, about 60 per cent., still further increased, and its tenacity as well. Manganese steel has its ductility lowered, but its non-magnetic properties remain apparently unaffected.

ONE of the most striking exhibits at the recent display of American railway appliances at Washington in connection with the International Railway Congress, was a 90-inch Niles driving-wheel chucking lathe, driven by a direct-connected 40 H. P. Westinghouse motor. This machine was designed for taking two cuts ½ inch deep, with 3-16 inch feed, at a speed of 20 feet per minute, and is capable of turning six pairs of driving-wheel tires per day of ten hours. As an instance of the capacity of the modern motor-driven machine tool in comparison with the older types of machines, it is interesting to note that the best practice of the latter is an average of scarcely more than two tires per day, while in many shops at the present time it takes from six to eight hours to turn a single pair of tires. The movable head of the 90-inch lathe was traversed by a 5 H. P. motor in order to provide for the quick removal of the wheels. The main driving motor had a speed range of one to two, which gives, with gearing changes, cutting speeds of 10 to 25 feet per minute on all diameters from 48 to 84 inches. The massive design of the machine is apparent from its principal dimensions:

Distance between face plates	6 ft. 8 in.
Swing over bed	92 in.
Diameter of face plates	90 in.

The machine will take wheels from 48 to 84 inches in diameter without changing the position of the carriages, and the face plates are driven by interval gears. Wheels can always be chucked close to the face plates.

ANOTHER interesting machine shown was a Niles heavy double-axle lathe, driven by a 20 H. P. motor. This machine was designed for simultaneously turning both ends of the heaviest car axles, and is capable of roughing and finish-turning the wheel fits and journals, and burnishing the journals of twenty car axles per 10-hour day. The carriages have an automatic feed release operated by collars on the rod at the front of the machine, and the axle is center-driven by a double equalizing driver. A light crane is provided at the center of the lathe for the speedy handling of the axles. The diameter of the hole in the central head of the lathe is 12½ inches, and the maximum distance between centers, 96 inches. As examples of the latest heavy power-driven tools, the equipment was significant to the delegates to the Congress.

A GASOLINE-MOTOR-DRIVEN rock drill is one of the latest mechanical novelties. It is an American device, and is intended for general drilling service, in mines and elsewhere. The advantages claimed for it are all those which the gasoline engine has established for itself—no need for a steam or compressed air supply, and

consequent compactness of outfit and economy of operation. The drill also is naturally self-contained, and it is claimed to be light and easily carried on mule-back or otherwise.

The German regulations concerning the public spark-telegraphy service came into force last April. These regulations, "Engineering" says, have been framed by the Imperial Postal Department in agreement with the Telegraph Conference held in London in 1903, under the presidency of Mr. R. K. Gray. The term "spark telegraphy" is officially adopted, instead of "wireless telegraphy," and the regulations distinguish between coast stations on shore or on ships at anchor, and ship stations. Lightships are supposed to communicate only with their particular coast station, and not to take dispatches from, nor for, ships out at sea, except in emergency cases. Messages may be drawn up in any of the languages approved by the London Conference. The limited signaling speed has necessitated the adoption of certain restrictions. Three new signals are introduced—the rest, or stop, signal, the distress signal, and the search signal. When the rest signal, consisting of six dashes, is sounded by any coast station, ships have to stop signaling. The search signal, . . . — — —., followed by the ship's name, is repeated out at sea until the reply, "Here," arrives. The distress signal, . . . — —'— . . . , is repeated until all other communications are stopped for the time. Before beginning to signal, every station must, by adjusting its receiver to the highest attainable sensitiveness, convince itself that it is not being talked to. Ships are not supposed to signal until they are within range of the nearest station. This range is, for the present, fixed at 200 kilometers (125 miles) for other coast stations, and at 120 kilometers (75 miles) for ships' stations fitted with masts 30 meters in height. The wave length is 365 meters. When a coast station calls, ships have to wait. When a call from a ship is not at once responded to, the call may be repeated three times, at intervals of five minutes; a fourth call may be made after an interval of an hour. So far, the public German coast stations on the North Sea and Baltic number eight, to which three more are added for limited public service. These stations are at Rixhöft, Arcona, Marienleuchte, Bülk, Heligoland, Cuxhaven, Borkum Lighthouse, Borkum Lightship, and Bremerhaven Lloydhalle, Weser Lightship, and Elbe I. Lightship. The list of steamers registered for spark-telegraphy service comprises thirteen vessels of the Norddeutsche Lloyd, the Hamburg-America Line, the Hamburg South Africa Line, and the Kiel-Körsör Line. Other ships, so far without code names, have to give their full names. Warships are not, of course, included in this list.

The only portion of the outside of a vessel's hull difficult to protect against rust is the "boot-top," or the portion between the light load-line and deep load-line. For this position, as remarked recently by Mr. A. C. A. Holzapfel in a paper before the Institution of Naval Architects, a mixture of zinc white, red lead, and boiled oil has generally been used, because the anti-fouling compositions do not stand so well in this portion of the vessel as in that which is constantly under water. Moreover, the boot-top is always much chafed by lighters, fenders, quay walls, etc., while the vessel is in port, and few captains care to recoat this portion with composition, partly because composition is more expensive than ordinary paint, partly because the sailors, who usually recoat the boot-top in port, are not past masters in the art of applying compositions, and lastly, because most compositions are liable to crack by long exposure to the atmosphere, thus letting the water through to the

iron or steel and causing rust. During recent years composition manufacturers have made special quick-drying and, at the same time, low-priced boot-top paints, some of which also have anti-fouling properties, and these have been largely adopted as a convenient substitute. The boot-top, however, is a part which it is difficult to keep free from rust, and where, after twenty years of trading, many vessels consequently show some perceptible diminution in the thickness of their plating.

AXEL SAHLIN

A BIOGRAPHICAL SKETCH

TO engineers on both sides of the Atlantic Mr. Axel Sahlin is a familiar figure. He is a native of Sweden, trained in America, a resident of Great Britain, his working field the Continent of Europe, an engineer well known and often seen in the industrial districts of Europe and America.

Mr. Sahlin's ancestors in Sweden for several generations were well-known iron masters and mine owners. Graduating from the Technical University at Stockholm in 1877, he served his apprenticeship in private shops and on the Swedish Government railways, and spent also a short time as inspector of railway material elsewhere on the Continent and in Great Britain.

Later he went to the United States, where he was employed for a number of years as an engineer in the blast furnace department of the Cambria Iron Company, at Johnstown, Pa. He was afterward engaged with the Pottstown Iron Company, the International Ore Separating Company, and the Maryland Steel Company, gradually gaining promotion until he became the general superintendent of the large works of the latter concern.

He left his position to represent, on the European Continent, the Brown Hoisting Machinery Company of Cleveland, Ohio, and later accepted the position as general superintendent of the Millom & Adkam Hematite Iron Company, Limited, of Millom, England, for which he engineered the making of considerably over a million tons of high-grade pig iron. At this time he held a leading position in the movement for increasing the product of blast furnaces, and demonstrated the practicability of economically producing in Great Britain a Bessemer iron low in silicon and sulphur.

In 1901 he was appointed a commissioner of the British Iron Trade Association to investigate the industrial conditions in the United States and submit a report on the manufacture of pig iron in America, and as such he visited the United States on a general engineering inspection tour in company with a number of other well-known British engineers and manufacturers.

In 1902 he formed a partnership with the well-known American metallurgical engineer, Julian Kennedy, of Pittsburgh, Pa. The new firm opened offices in London under the name of Julian Kennedy, Sahlin & Company, Limited, and soon extended their operations to the European Continent. The firm recently opened branch offices in Paris, and are represented in Germany and Austria. They have designed and built a number of important plants for iron and steel companies in the United States and in Continental Europe, and have also been widely engaged as experts and investigators of financial and mining propositions. Mr. Sahlin is now making London his headquarters.

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GEORGE GIBBS

CHIEF ENGINEER OF ELECTRIC TRACTION FOR THE NEW YORK CITY TERMINAL OF THE PENNSYLVANIA RAILROAD

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CASSIER'S MAGAZINE

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THE NERVES OF A RAILWAY

BLOCK SIGNALLING SYSTEMS ON AMERICAN RAILWAYS

By Day Allen Willey

TO the one familiar with the service on the modern railway the title "nerve" will be deemed appropriate when used in connection with the various appliances employed to indicate the positions of trains on the several portions of a line. Such intelligence enables the engineer to calculate his position with reference to other trains in his vicinity and to regulate his speed accordingly. Just as the nerves of the human system keep the brain acquainted with the condition of the body, so the signals keep the train crew acquainted with the condition of the line.

The systems for conveying such intelligence are necessarily varied to suit the conditions, but generally speaking they may be divided into two classes,—those for the guidance of trains en route between stations, and those controlling the movements at terminals, yards, sidings, and junctions. In this article the writer will not attempt to describe all of the methods for train control, since space would not permit it, but shall confine himself to some of the principal forms of block signalling employed on the greater American railways and to the plans devised for handling traffic, and its safe and regular maintenance at junctions, terminals, and other points.

Three hundred years ago, persons communicated with one another by means of wooden arms adjusted to posts, capable of being set vertically, horizontally, or diagonally, the position of the arm conveying the intelligence. The same idea is employed more extensively than any other to-day in railway signal service, for the semaphore is considered the most reliable and practical form of visual communication by day, while at night the lantern attached to it makes it equally effective.

So, whether the semaphore be moved automatically or by the pull of a hand lever, it is the principal means of indicating track condition on the divisions of a block railway, while it is of equal value in indicating whether terminal and other tracks

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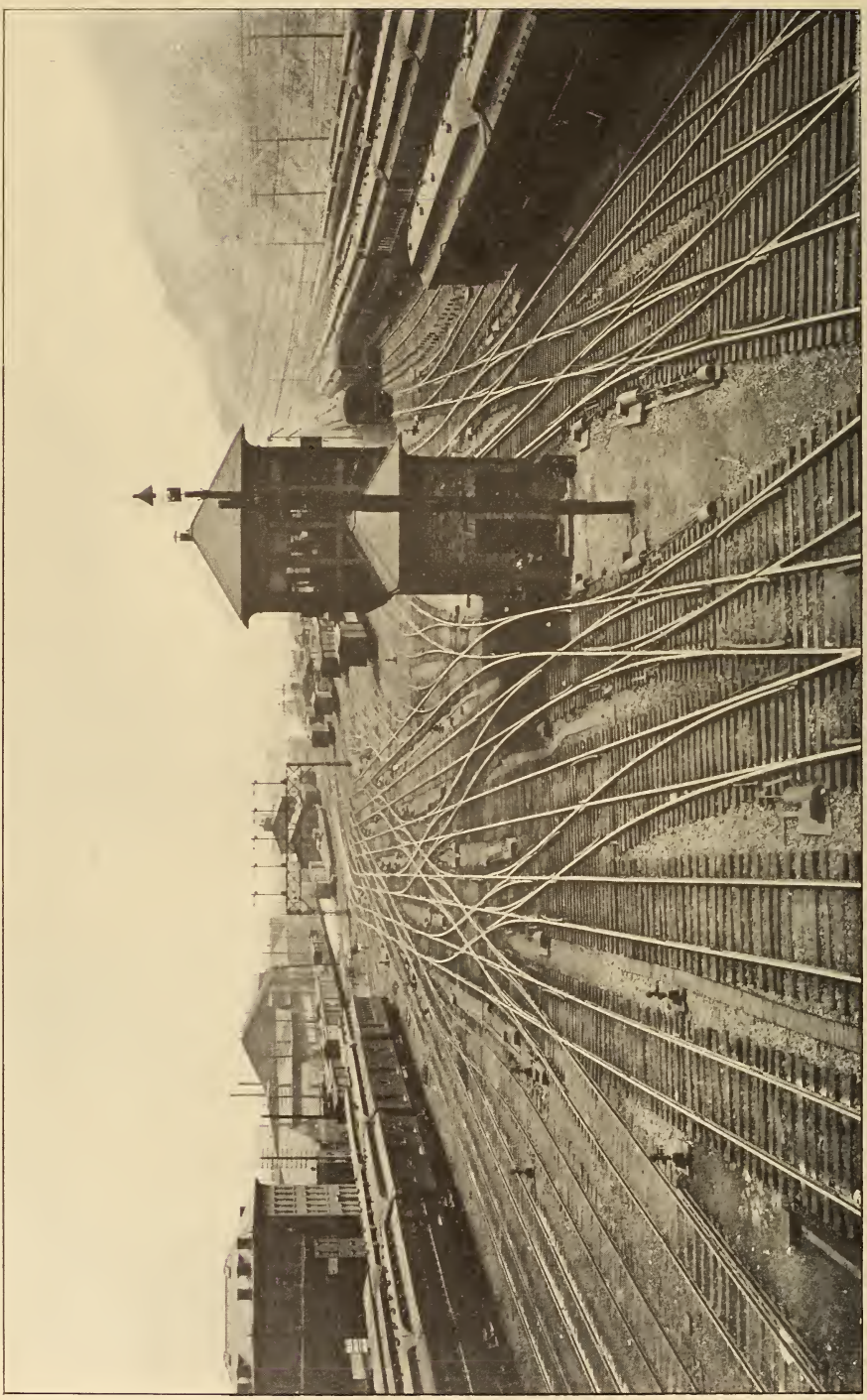


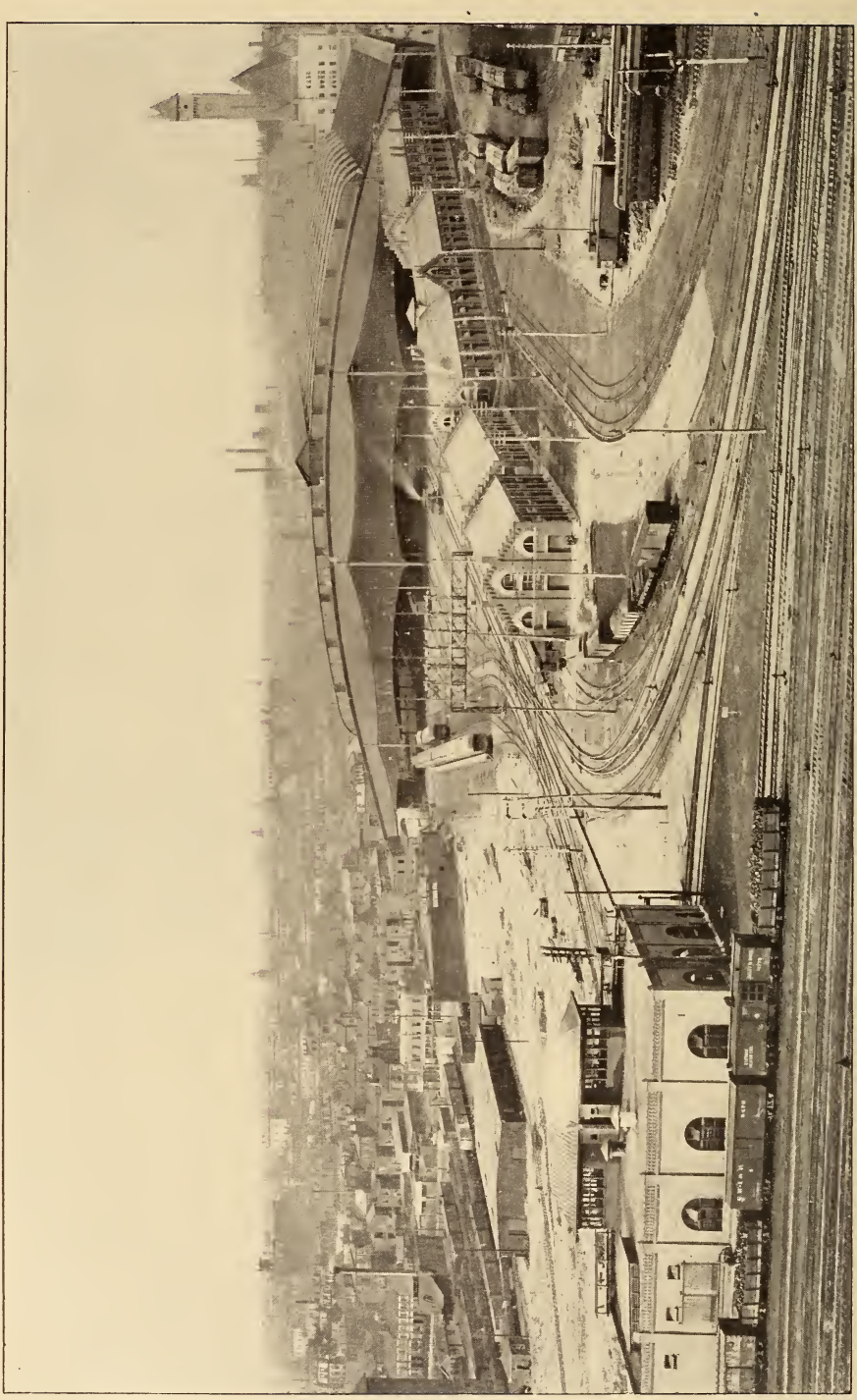
ARCH SYSTEM CONTROLLING LINE THROUGH YARD. THE SIGNALS SHOW THAT ALL OF THE MAIN LINE AT THE STATION IS BLOCKED

MANUALLY OPERATED BLOCK SIGNAL IN USE IN CONNECTION WITH DOUBLE-TRACK MAIN LINE AND SIDINGS. HOME SIGNAL AT DANGER. THE NEAR SEMAPHORE INDICATES TRAINS ON SIDINGS

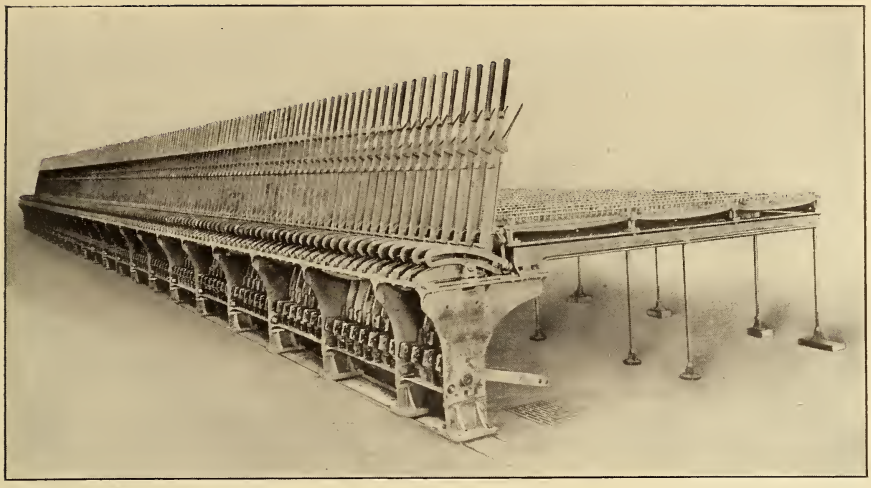
are free or occupied. The semaphore, the train staff, and the disc signal are utilized on about all of the 40,000 miles of lines in the United States where the block system has been adopted.

In installing the semaphore, the posts, or arches sustaining it, are placed at each division point or at each block terminal, the distance apart depending on the length of the block. It may be several miles in length where traffic is infrequent, or less than a mile long in other places. On some sections of the Pennsylvania Railroad between Philadelphia and New York the semaphores are so near together that the writer has counted three in a minute, while traveling from one city to the other on a fast express train. This is one reason why the post or arch supporting the semaphore usually carries not only the local or home signal, but also an arm, which indicates the condition of the block beyond that which the train is about to enter.

Sometimes three arms are set on



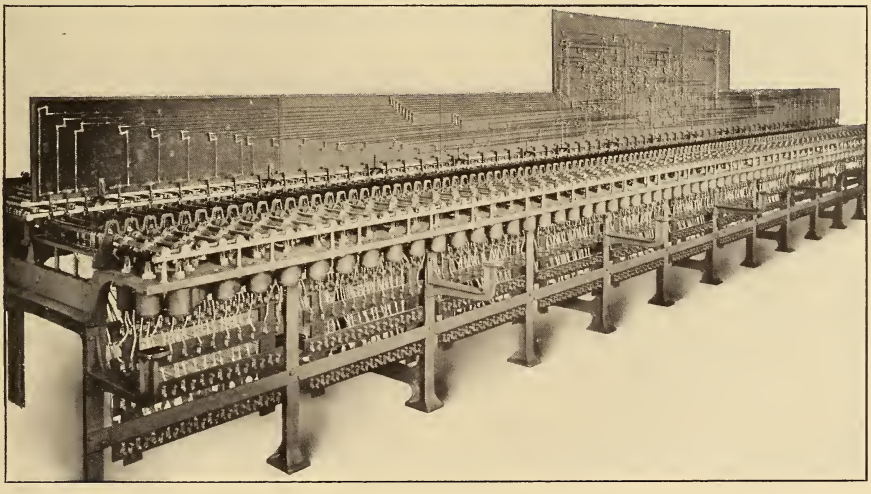
A BAD PLACE FOR THE ENGINEER. AN EXAMPLE AT ST. LOUIS OF STATION CONNECTED WITH MAIN LINE BY TERMINAL Y TRACKS



A LEVER BOARD IN A MODERN MANUALLY OPERATED INTERLOCKING SWITCH SYSTEM SERVING A LARGE YARD

one post, as shown on page 260, one for the block immediately ahead, the second for the one beyond, and the third for the one beyond the latter. The top semaphore represents the nearest block, and the lowest the one most distant. Where the locomotive is running at the rate of fifty miles an hour the three-signal post is essential to the safety of a short block system, since considerable track room is needed to bring the train to a full stop, especially on a level or a down-grade.

As already stated, the block signal may be controlled from a station at the end of each track division. As the train enters, the operator by pulling a lever throws his signal to the danger position, the lever being connected with the semaphore by heavy wire passing over pulleys at curves. Usually the telegraph or telephone aids in this manual block service, as



AN AUTOMATIC INTERLOCKING SWITCHBOARD, SHOWING MECHANISM OF AN ELECTRO-PNEUMATIC SYSTEM

WORKING AN AUTOMATIC INTERLOCKING SWITCHBOARD IN A TERMINAL STATION TOWER. THE POSITION OF EVERY SWITCH IS INDICATED ON THE MAP ON THE BOARD IN FRONT OF THE OPERATOR

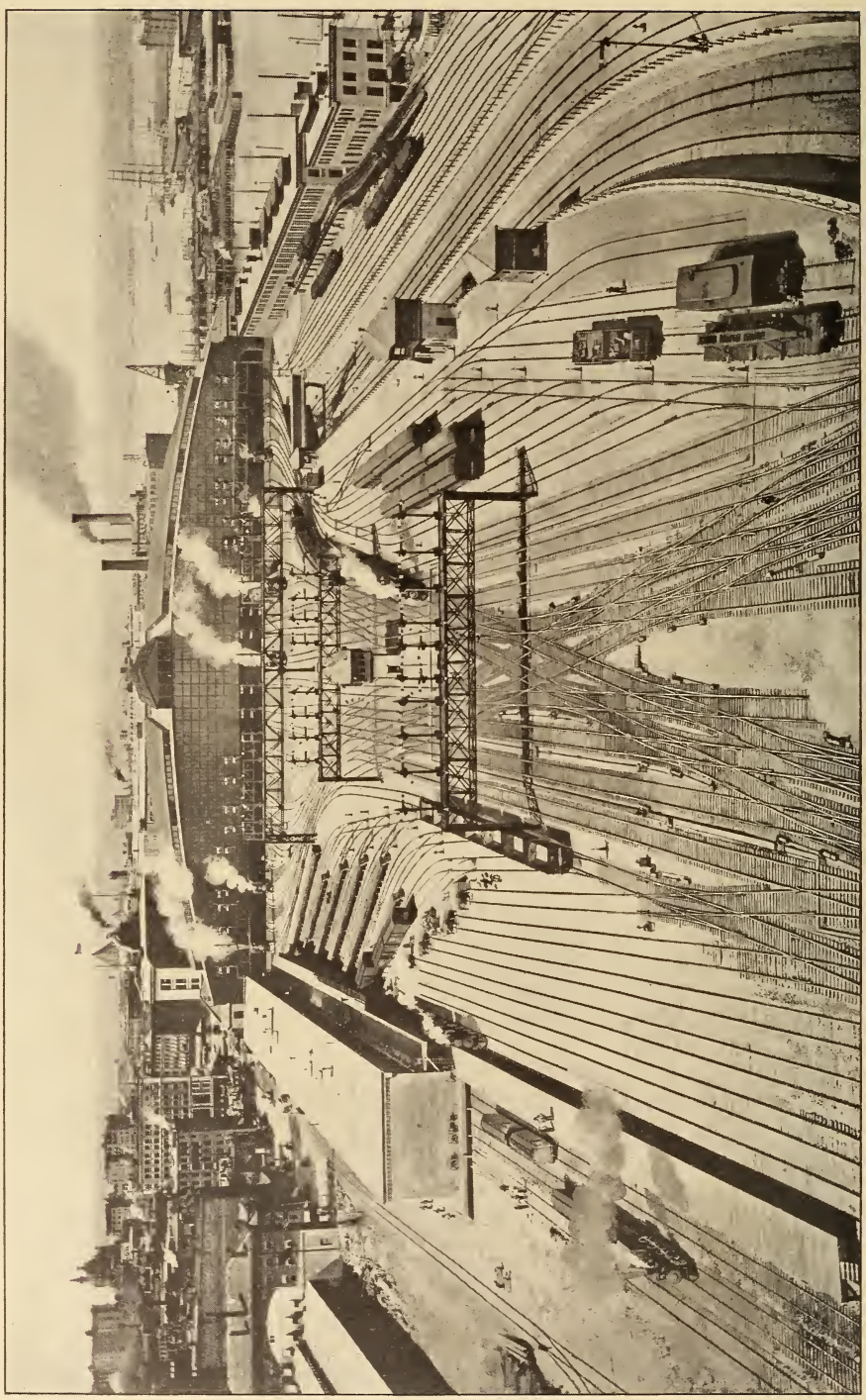
SIGNAL ARCH ON A FOUR-TRACK LINE. THE TRAIN SHOWN HAS SET DANGER AND CAUTIONARY SIGNALS BY PASSING INTO THE BLOCK

the operator announces the train position to the operator at the next station, who sets his signal accordingly.

The automatic block system, however, has found much favour, especially on lines where the traffic is very heavy, as through it the train service is literally controlled by the passage of the trains themselves. Thus when one train enters a block it sets the signal behind it at danger and the one in the rear of this at cautionary, lowering the semaphore arms to the safety position as it leaves the block.

One of the automatic block systems most extensively employed is the Westinghouse electro-pneumatic.

Its essential feature is an electric current flowing through the track rails. The signal being at the entrance of a block section, which is, say, three-quarters of a mile long, the battery for the current is at the outgoing end; and when the rails throughout the section, and also the rails of the side tracks and cross-overs, so far as they foul the main track, are clear,—not occupied by wheels at any point,—the circuit of the battery is through the right-hand rail of the track to the electro-magnet at the signal, thence to the left-hand rail and by that back to the battery. This circuit being closed, the electro-magnet at the signal is energized and holds the signal, through the medium of a stronger electro-magnet, worked by a lock battery in the all-clear or go-ahead position. The entrance of a train short circuits the current through the wheels and axles, de-energizing the electro-magnet, and the signal, by force of gravity, assumes the stop position, thus warning the next following



A BOSTON RAILWAY TERMINAL WITH ELECTRICALLY CONTROLLED CROSSINGS AND SIDINGS. THE ENTRANCE TO THE STATION IS DIVIDED INTO THREE OF WHAT ARE PRACTICALLY THE SHORTEST "BLOCKS" IN THE WORLD

train not to enter the section. The signal remains at "stop" until every pair of wheels has passed out of the section.

The lower arm on each post is always a distant or cautionary signal, informing the engineman of the position of the "home" or stop signal at the entrance of the next succeeding block section. This provision is made for the purpose of avoiding loss of time during fogs, or whenever the engineer cannot see a stop signal until he comes within a short distance of it. The distant signal gives him notice at least a block ahead of the position of the home signal, whether or not he is to be stopped by it, so that in spite of fog or darkness he may run at a high speed, provided he can come to a stop in the space between the signals. The distant signal is controlled by the movements of the corresponding "home" through the medium of a wire on poles; or by means of a polarized relay, it can be controlled by the track circuit of the section between the home and its corresponding distant signal. This does away with the line wires and obviates certain disturbances by lightning.

The power for moving the arm to the downward or all-clear position is compressed air, of about 70 pounds pressure per square inch, acting through a cylinder fixed in an iron box at the foot of the signal mast. The pneumatic pressure is conveyed from a compressor to the several signals along the line, for a distance of 10 to 20 miles, by means of an iron pipe buried in the ground. In moving a semaphore arm, the air entering the cylinder at its upper end forces downward a piston which by its lever pushes up the signal rod inside the cylindrical iron mast and thereby moves the arm of the signal downward.

On releasing the pressure, which occurs when a train enters the block section, the signal arm flies to the horizontal or stop position by gravity, a counter-weight on its left-hand end, with the vertical rod inside the post, accomplishing this. An accidental failure of air pressure would have the same effect, throwing the signal to the stop position, thus bringing to a stand any train which might come along, and compelling the engineman to report the cause of the failure, which the inspector then seeks and removes.

The air cylinder is kept charged by means of an electro-magnet valve. This is operated by merely closing the track circuit. The de-energizing of the magnet on the entrance of a train is due to the fact that nearly all of the electric current flows from one rail to the other through the wheels and axles of the cars, as before explained.

In night service the indication of a clear block may be given by showing a white light on the semaphore tower. When the arm of a home signal assumes the horizontal or danger position, a red glass is set in front of the light. On a number of railways the all-clear indications is now green instead of white, and in such cases the distant signal also shows green for all clear, while for the caution indication the distant signal is made to show on some roads, yellow, and on others a combination of red and green, a red light and a green light being fixed close together, side by side.

The three-position signal has found considerable favour during the past few years. With this arrangement the single arms serve both as home or distant positive signal and also as a distant or cautionary. For example, the semaphore placed horizontally indicates stop; when hanging downward at an angle of 45 degrees from the horizontal, it indicates all clear for that section, but means also (the same as a distant signal) "be prepared to stop at the next signal;" when downward in a practically vertical position, it indicates all clear for its own section.

In the operation of the disc signal in controlling trains, compressed air

A THREE-BLOCK SIGNAL POST IS ESSENTIAL FOR SAFETY WHERE THE BLOCKS ARE SHORT

is usually dispensed with, the electric current being sufficiently powerful to move the light mechanism employed. Here again, the home signal is always set at the top and the distant immediately below it. The signal portion of the disc is generally composed of some light but strong fabric. The framework holding it is balanced on a pivot connected with the armature of an electro-magnet. The force of gravity maintains the home and distant signals at danger and caution, respectively, when a train is in the block, but as soon as the last wheels have left the section, the current energizes the magnet which conceals the home disc in its socket in the signal mast and sets the cautionary signal at "way clear."

AUTOMATIC DISTANT AND HOME SIGNAL COMBINED, SET AT "TRACK CLEAR"

These signals are worked by an electric motor fixed in a box at the foot of the post, a motor for each post. All of the motors along a stretch of 10 to 20 miles of line are actuated by current from storage batteries which are kept in wells sunk in the ground near the signal, and the batteries, in turn, are charged by a dynamo situated at the central point. The double copper feed-wire is strung on the telegraph poles. Signals moved by electric motors are now made by a number of different companies and are in use on half a dozen railways.

In train control at yards and terminals the most common form of interlocking is that in which the several switches are connected to levers

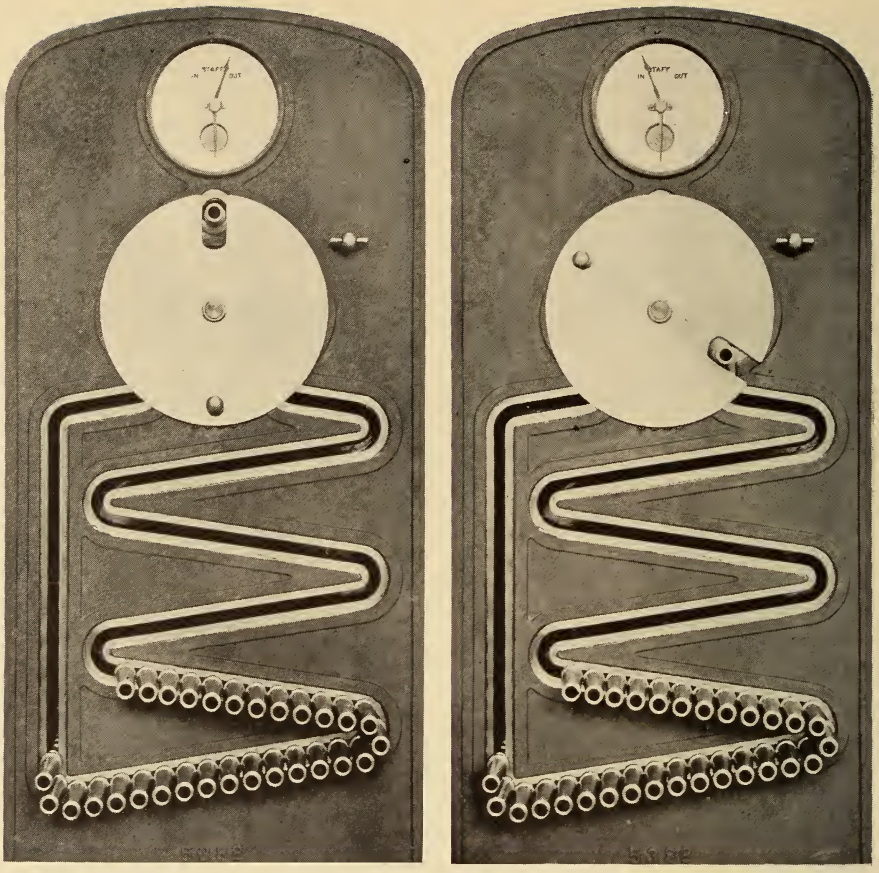
TRAIN SEEN IN DISTANCE ARPROACHING "CLEAR BLOCK." THE TRAIN STAFF IS SHOWN SUSPENDED FROM THE POST IN THE MIDDLE FOREGROUND, READY TO BE TAKEN OUT AS THE TRAIN PASSES AT FULL SPEED. THE SEMAPHORE IN THE FOREGROUND IS SET FOR OCCUPIED SIDING

in the switch tower by rods of gas pipe, supported on posts close to the ground. The levers moving these rods, perhaps twenty, fifty, or a hundred in a single frame, are all mounted on the same axis. For signals (but not for switches) wires may take the place of the rods.

In large city yards and at the entrance to stations, it often happens that the space occupied by the signal rods is needed for tracks or buildings, and for this and other reasons compressed air and electricity have been introduced for working the switches and signals, the air pipes or electric wires being buried in the ground. The most familiar type of the power switch-and-signal machine is the electro-pneumatic, in which the functions are performed on the same general principles as with the block signals, the signals of the interlocking plant being worked by pneumatic pressure. A cylinder for a switch is usually installed horizontally at the side of the track to be moved. The movement of the switch

DELIVERING A TRAIN STAFF BY HAND TO A TRAIN ENTERING A BLOCK AT FULL SPEED

LOCOMOTIVE WITH AUTOMATIC TRAIN STAFF CATCHER, SHOWN ON FORWARD PART OF THE TENDER



FRONT OF TRAIN STAFF MACHINE

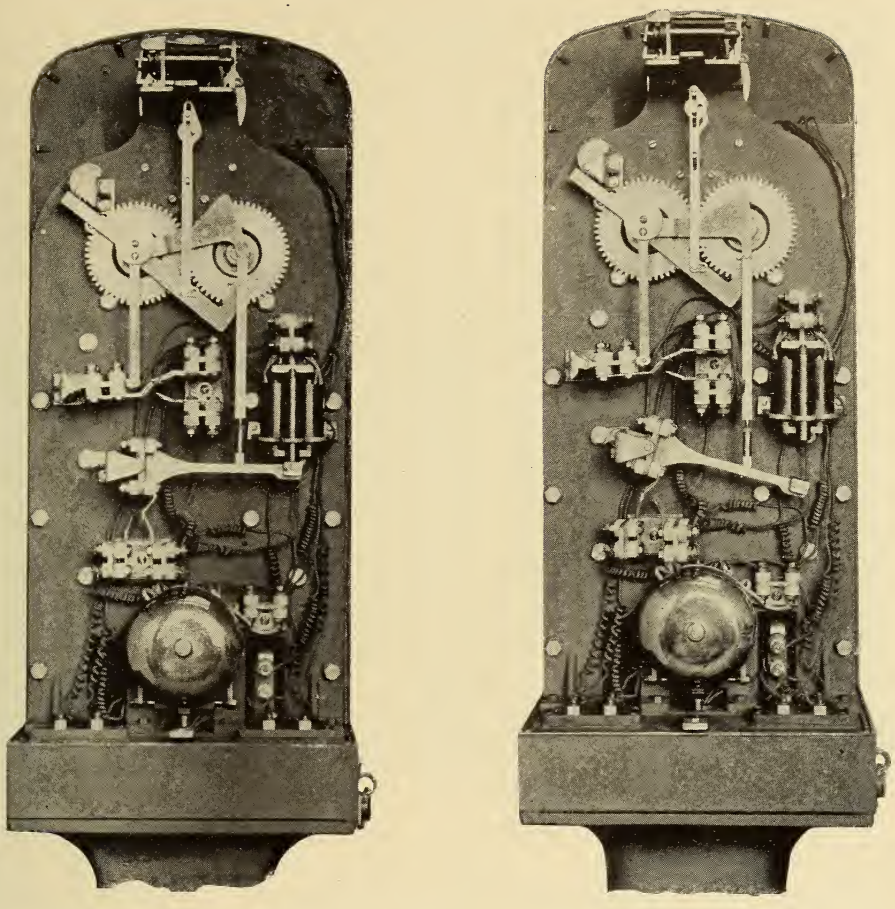
Staff in Disk, Ready to be Released. Signal Set at "Block Clear"

Staff Out. Signal Set at "Block Closed."

conveys an electric "indication" to the switch tower to insure that the go-ahead signal for that switch shall not be given prematurely. Besides the usual mechanical interlocking of one lever with another, the electro-pneumatic machine provides additional safeguards in the way of magnetic locks.

With a power machine the work of the signalman is reduced from that of pulling levers, weighted with heavy loads, to the turning of the extremely light handles at the front of the machine. By these handles long horizontal rods are rotated on their axes, which in their revolution close electric circuits thereby actuating the air valves. The interlocking is effected by longitudinal and transverse rods at the top of the machine.

In some plants a diagram of the yard is attached to the machine. Metal strips represent the tracks. These are movable, so that any operation which takes place on the ground by the act of the signalman is reproduced in minature before his eyes. In short, the diagram continually checks the accuracy of his work. It is in the operation of the lever or power switchboard that the modern method of train control is perhaps most strikingly demonstrated, for by the employment of the pneumatic key, one man may guide the train

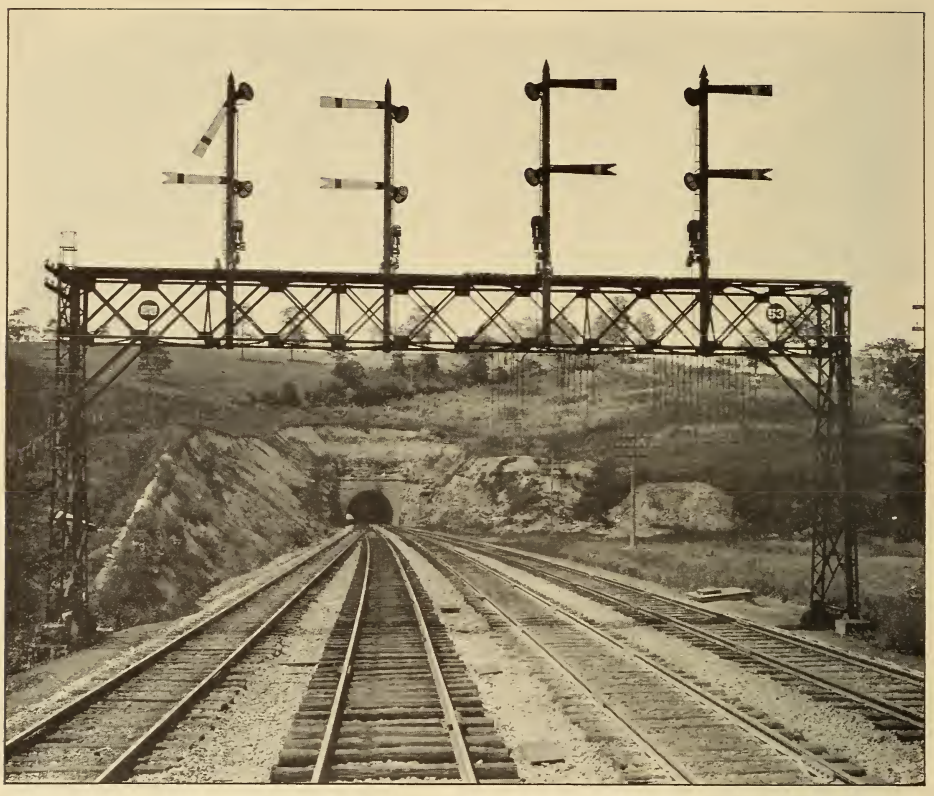


REAR VIEWS OF MECHANISM OF TRAIN STAFF MACHINE. AT THE LEFT THE MACHINE IS SHOWN SET FOR REMOVAL OF THE STAFF, WHILE AT THE RIGHT THE MACHINE IS SHOWN LOCKED, WITH ALL THE STAFFS IN

movements along a dozen main tracks and sidings, and a half dozen men control the terminal traffic of a great trunk line.

The train staff system of to-day is the development of a simple principle for the operation of railways which was recognized in Great Britain as early as 1840; namely, that to safely pass over a given section of single track, every train should have in its possession a tangible right to do so in the form of some specific article of which there is only one obtainable. The first train staff was a metal bar about two feet long, which had cast or engraved on it the names of the two stations between which it alone gave authority for any train to proceed. Unless trains moved alternately in opposite directions the staff had to be returned over the section by a special engine, or in some cases by a vehicle along the nearest wagon road.

This plan became impracticable with increase in traffic and more frequent train movement. The staff-and-ticket system was therefore devised, in which device the original staff became a key that would unlock a box at either end of the section and permit tickets to be taken from it. If it was desired to forward, say, three trains from one station to another before one should



A SIGNAL ARCH ON THE PENNSYLVANIA RAILROAD, PROTECTING A TUNNEL SECTION

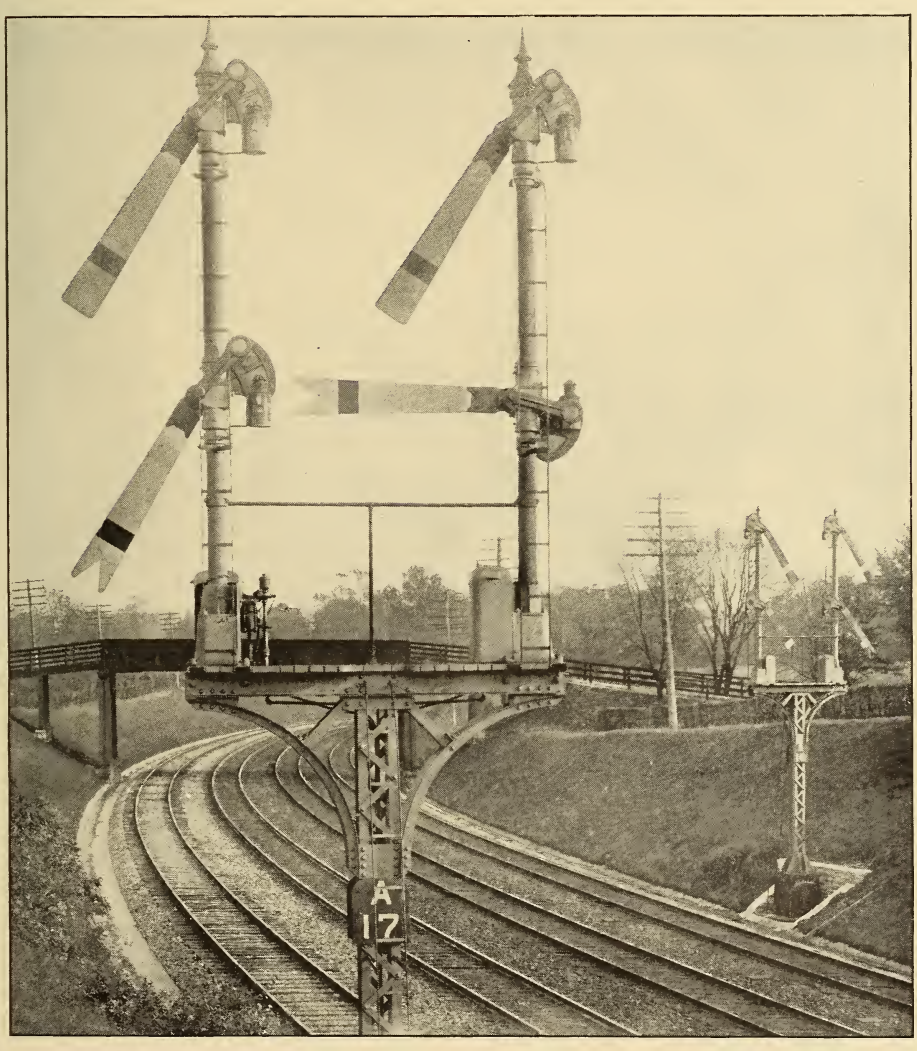
proceed in the opposite direction, the ticket box was unlocked by the staff and a ticket given to the first and second trains, the third train receiving the staff. Since an engineer or guard of any train when receiving a ticket was required to see the staff as well, this system, while making head-on collisions impossible, did not permit trains to enter a section from the end at which the staff did not happen to be.

To accomplish this result Mr. Edward Tyer, in 1878, introduced his electric tablet apparatus, which consisted of two instruments, one at either end of a section, each instrument containing a certain number of tablets, any one of which constituted the right of a train to pass over that section. The two instruments were electrically connected and synchronized so that the removal of a tablet from either instrument absolutely prevented any other being taken out.

In 1899, Mr. F. W. Webb, the chief mechanical engineer, and Mr. Thompson, the signal superintendent of the London & Northwestern Railway in Great Britain, invented what is known as the Webb & Thompson electric train staff, in which staffs were substituted for the tablets in the Tyer system, and a permissive feature added whereby several trains could follow one another into a block section if desired, in a manner similar to that employed in the non-electric staff and ticket system. The Webb-Thompson machine, which was described by the writer in a recent article in this magazine, relative to transportation in Great Britain and in America, has been adopted on all American railway lines which have thus far utilized the train staff,

either on the whole or a portion of their mileage. It may be added that all of the American apparatus is made in America at the plant of the Union Switch & Signal Company and installed by them.

The staff has found especial favour at points where the traffic is so great that it is practically impossible to establish a reliable time-table for trains, and where their despatch by means of the telegraph or telephone would cause too much delay. One illustration of this is shown on the Chicago, Milwaukee & St. Paul Railway, where the lines of the southern division cross the Mississippi River. Over a single track passes the traffic of no less than 3000 miles of railway, necessitating the movement of fifty trains daily on an average, in addition to the switching of the cars in the yards on the east side of the river. A block three miles in length was established, including the bridge crossing the Mississippi River,



DETAIL OF AUTOMATIC BLOCK SIGNAL, SHOWING METHOD OF ATTACHING LAMPS AND DISCS OF COLOURED GLASS FOR NIGHT USE

and a card system was adopted, the engineer of one train receiving a card giving him permission to enter the block and deliver the card at the end, the delivery being announced by telegraph to the station at the other terminus. The cards were discontinued partly because it was impossible to "interlock" them as could be done with the staff.

The Webb-Thompson apparatus was finally installed, and according to the officers of the company has given entire satisfaction on account of its capacity and simplicity. When a train is to enter a block, the operator in charge signals to the operator at the other end for a staff, the second operator controlling the staff machine at the first station. The staff can be delivered to the engineer in five seconds from the time he reaches the block in case he is held there for a train ahead to get out of it.

If repairs are to be made to any point inside of the block and the aid of a work train required, this is so protected by the staff system that no flagman need be sent out; consequently there is no delay in recalling the flagman when the train is ready to proceed.

Where the train movement is regular, the trains are despatched so rapidly that "tie-ups" are of very rare occurence, although, as stated, the block consists of a single track. It may be added that the Chicago, Milwaukee & St. Paul Railroad was the first company to employ the train staff in the United States. Some of the lines now using it are the Chesapeake & Ohio; Cincinnati, New Orleans & Texas Pacific; Atchison, Topeka & Santa Fe; Chicago, Rock Island & Pacific, and Canadian Pacific.

In working with the train staff, both hand and mechanical methods are utilized for taking the staff from the engineer and delivering it to him, depending upon the speed of the train. The staff commonly used is only six inches in length and weighing less than half a pound, can be delivered to the engineer even if the train is running at a speed of 25 miles an hour. It is handed to the engineer by means of a rattan hoop, the method followed being similar to that used on many railroads for transmitting what is technically called the "19" order and clearance cards to avoid delay in stopping.

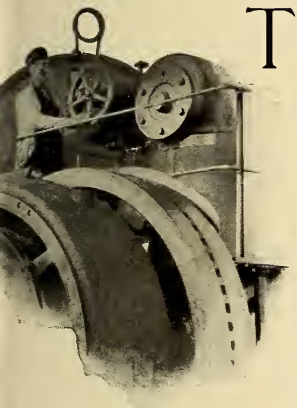
But for high-speed express trains, averaging 40 and 50 miles an hour, the delivery of staff signals is entirely practicable by using mechanical catchers and receivers. These are installed on the front portion of the engine tender, and at a convenient point by the side of the track in proximity to the staff machine, so that the staff can be placed in the catcher as soon as the latter is unlocked by the operator at the station controlling the other end of the block. It is taken from the catcher by the engineer in the same manner as mail bags are caught up at a station without slacking speed.

Tests made on the Cincinnati, New Orleans & Texas Pacific system have shown that the engineer can receive this mechanical order to enter the block while running at a rate of fully 60 miles an hour; consequently the staff system is available for the service of limited and other high-speed trains.

MODERN BRITISH HIGH-SPEED STEAM ENGINES

By Leo H. Jackson

PART I.—TYPICAL FEATURES



THE prevailing type of high-speed steam engine in present-day use is undoubtedly the double-acting compound or triple-expansion engine with forced lubrication. Perhaps in the whole range of steam engineering, with the possible exception of the locomotive engine, there is no more striking example of fitness for its work, no better adaptation of means to an end, than exists in this peculiar boxed-up machine, direct-coupled to its dynamo.

The conditions call for compactness, for an abnormally quick rate of revolution; for the necessity of lengthened runs without stoppage for any purpose; for even turning effort; accurate governing; and, lastly, for all these requirements to be fulfilled with the minimum of attention. How well, even admirably, these rather difficult conditions have been fulfilled, the examples given in the following pages will show.

We are so accustomed to demand from the engineer that he shall produce, say, a prime mover, or, in fact, any piece of machinery whatever, which shall effectually fulfil the most difficult conditions, that no one now-a-days is astonished to hear that engines are being built which can, and do, run for six months or more at a time without a single stoppage for any purpose whatever. Doubtless this performance can be paralleled and even beaten by some slow-moving and ponderous pumping engines, which, officially at any rate, never cease their laborious heave and push from one year's end to the other; but the engines we have in view are no such lethargic machines.

Eighty-five millions of revolutions without a stop, are quoted in one engine builder's report. A familiar illustration will help us to appreciate what this means. A locomotive engine with 7-foot driving wheels makes 240 revolutions per mile, and such a run would be equivalent to more than three hundred and fifty-four thousand miles, or from the earth to the moon and half-way back again. At an unbroken speed of sixty miles an hour, this would occupy just over eight months. This is sufficiently remarkable in itself, but any railway man would tell us that such a mileage, under the ordinary daily working conditions, would represent half the efficient life time of some locomotives, and would, in any case, have entitled the engine to an extensive course of repairs. But we learn from the report of the high-speed dynamo-engine above referred to, that after running almost continuously day and night from May, 1896, to September, 1899, making, in a year, 99.77 per cent. of the total time possible, the engine was opened out, and no repairs and practically no adjustments were required.

The writer has not the dimensions or speed of this particular engine before him, but it may safely be assumed that it was making something between 300 and 400 revolutions per minute, during the whole of the time, and

was still running "absolutely noiselessly." How are these really wonderful results accomplished? To put the answer into a few words:—Firstly, by perfect workmanship—the individual parts must be dead true, and their combination in perfect adjustment. Secondly, the working surfaces, after being as accurately fitted as human skill can make them, must, while in work, be kept from actual contact by an ever-present film of oil, supplied under pressure sufficient to ensure that it shall not be squeezed out, under the greatest load the bearing will be called upon to sustain. Thirdly, the design must be adapted to the conditions.

All these are of equal importance —design, lubrication, workmanship; workmanship, lubrication, design,— and nothing else is needed, it being only reasonable to suppose that no one would willingly put inferior materials into a work of this kind. The writer hopes that the several makers whose designs will be illustrated in Part II of this article will forgive him for having given away their trade secrets in this manner, and, with their permission, he will now go a little further into detail concerning the design, which, it is to be understood, is the outcome of investigation and experience extending over a good many years, and contains some features which could hardly have been premised.

In structure the modern high-speed engine is a dwarf,—a dwarf with a giant's strength, it may be said—and a section of one of these engines, seen for the first time, always suggests, with its massive crank-shaft and ludicrously short connecting rods, that one is looking at an engine of ordinary proportions through a distorting glass, which exaggerates the breadth at the expense of the height.

Another peculiar feature is the absence of all the elaborate means of adjustment for taking up wear which one would naturally expect to find in an engine intended for such high speeds. Everything is of the simplest and plainest character, and every bolt, nut, screw or pin is absolutely secured against the possibility of working loose. Automatic expansion gear has practically fallen out of use, from its inability to withstand the stress and strain of such rapid rotation.

Steam-jackets also are a thing of the past, the amount of steam passed through the cylinder being so great, as compared with slower-moving engines, as to make the provision of a jacket needless.

The description of the standing and running parts of the engine which follows is of a typical character, such as is more or less followed by every maker, and is intended to save repetition later on. Deviations from standard practice will be dealt with as they arise in describing the examples of each maker's latest practice.

The structural or fixed parts of the engine consist of, (*a*) the bed-plate; (*b*) the casting; (*c*) the distance pieces, forming also the crosshead guides; and (*d*) the cylinders and steam-chests. The bed-plate is little more than a strong rectangular box casting, forming also the oil well, planed on its upper and lower surfaces, and carrying the main bearings. These are of the simplest possible character, consisting merely of semi-circular recesses formed in the four transverse ribs of the bed (for a two-crank engine) which, after being fitted with plain, strong caps, are bored out and faced on each side at one operation.

The brasses (which, by the way, are usually of cast iron, lined with white metal) are in two plain turned shells, easily removable when the caps are taken off, without lifting the crankshaft. The bottom of the bed-plate slopes in each direction towards a recess in which the suction pipe of the oil pump is located.

The casting is a rectangular cast-iron box, sometimes with semi-circular ends, fitted with convenient inspection doors and planed on top and

bottom surfaces. This is bolted by its lower flange to the bed-plate. Formerly the cylinders were directly fixed upon the top of the casing, but (and this is one of the points which could hardly have been foreseen in the original design) it is now the universal practice to interpose a trunk or distance-piece between cylinders and casing. It has been found by experience that the piston rods, being plentifully besprinkled with the oil, splashed up within the casing, convey this oil into the cylinders to such an extent as to load the steam with greasy particles, to be later on deposited on the tubes of condenser or water heater. The trunk or distance piece, being of a depth not less than the stroke of the piston, insures that the portion of piston-rod exposed to the splash shall never enter the cylinder at all.

The trunk, besides forming the bottom cylinder cover, descends into the casing, and its lower part is bored to act as cross-head guides. Here is another labour-saving contrivance, largely, but not, the writer believes, universally adopted, in that the hole in the top of the casing through which the trunk passes does not fit the latter closely, but allows of a little lateral movement. The exact position of the two trunks, relatively to the two cranks beneath, is found by the erector, and the trunk-flanges are secured to the casing when dead in line with centers of crank throws by turned and rimmered bolts. By undoing these bolts, disconnecting the steam and exhaust pipes, and the brasses at the lower end of the connecting rods, it is possible to lift the cylinder complete with its distance piece, piston and rod, crosshead and connecting rod right up and out of the casing for examination and adjustment.

In larger engines it is frequently the practice to cast the cylinders with an internal flange all around the bottom end, to which the lower cylinder cover is secured internally by screws. By taking off the top cylinder cover and removing the piston by unscrewing the large nut by which it is secured to the rod, the bottom cover can be got at, and this being loosened, the whole line of piston-rod, crosshead, and connection rod can be drawn up without interfering with any steam pipe connections or disturbing the cylinder.

So far the writer has proceeded upon ground practically common to all who manufacture this type of engine, but beginning with the cylinders, a sharp line of demarcation is observable between two opposite systems in use. The writer is not even prepared with an opinion as to which is best,—the respective makers know very much more than he about the value of their own practice,—but he will content himself with describing the two different systems in parallel, and leaving the reader to judge for himself

The problem is this:—Shall the two cylinders of a compound engine be formed in one piece, with a central double-staged piston valve which effects the whole duty of steam distribution—inlet and exhaust—for both cylinders, being actuated by a single eccentric; or shall each cylinder stand separately, with its own independent piston valve?

The adherents of the latter system say, and with much weight, that by placing the cylinders back to back with the steam chests, and their piston valves outside, they obtain a better balanced engine, as the cranks are closer to each other, and the rocking couple, or the tendency of each set of reciprocating parts to vibrate its own end of the bed-plate, independently, is reduced.

Another important advantage is in the separation of the high-pressure and the low-pressure valves. At the present time, when the highest economy is sought, and the increasing use of the superheater at one end and the condenser at the other introduces a very great range of temperature in the engine, it is evident that it is more conducive to economy to

have the two valves separate, thereby reducing the amount of condensation which must necessarily take place in a valve which has high-temperature steam on one side and condenser temperature on the other, while the bad effects of expansion under these conditions are, to a very great extent, if not altogether, overcome. Then again, there is the advantage of having each valve on its own rod, and driven by its own eccentric, so that adjustments may be made on each valve independently when necessary.

On the other hand, the makers of engines with the steam chest between the two cylinders, point to recorded results which can hardly be surpassed. The central valve which serves both cylinders amounts practically to two complete, if not actually separate, piston valves, superposed on one spindle and driven by one eccentric.

The high-pressure valve takes steam between its two pistons, and exhausts through its central cavity or passage, into that of the low-pressure valve, which, on the other hand, admits and cuts off its steam by its outer edges, exhausting finally from between its pistons to the condenser, or into the open air. The one is a central admission valve, and the other a central exhaust valve.

It is objected to this type of valve that its broad and heavy single eccentric is the only unbalanced revolving part of the engine, and this introduces us to another very frequent variation, in which the low-pressure valve is between the cylinders, and the high-pressure steam chest and valve outside, each with its independent eccentric balancing the other. Piston valves are invariably used for the high-pressure cylinder, and, with few exceptions, for the low also.

With superheated steam, difficulty has been experienced from the distortion of the liner or tube in which the piston valve works. The cylinder casting, with its varying thickness of metal, does not expand uniformly when heated, with the effect that a forced-in liner cannot retain its true cylindrical form. This difficulty has been successfully overcome by the ingenious expedient of making the liner an easy diametrical fit in the cylinder casting; steam tightness being secured by four narrow stepped flanges, or circular ribs, formed internally in the cylinder body and externally on the liner, a thin copper or asbestos ring being inserted between each. The liner is then slipped into its place, and firmly held down, either by the top cover itself, or by long screws tapped through the latter. The ports are cut through the liner, generally in the form of diagonally-disposed slots.

The great height of the cylinder body, relatively to the length of stroke, is a noticeable feature in these engines, the actual working barrel being less than one-third the total height. The length of steam chest is the governing feature in this dimension, and, owing to the necessity for very short and straight steam-ports, with a relatively long valve travel, it will be seen that very deep covers are required to make up the cylinder length to that of the steam chests, if the casting is to be of uniform height throughout.

These deeply recessed covers are utilized by being filled up with non-condensing material, and the lower covers afford the opportunity of getting in very deep stuffing-boxes, usually adapted for receiving metallic packing. The conical surface of the covers and pistons are well calculated to free the cylinder of water by gravitation. The percentage of clearance volume, even with the shortest steam-port, is very high, owing to the fact that, whether the stroke be long or short, sufficient space must be allowed at the ends of the stroke to avoid the possibility of the piston striking the covers. The wear of brasses in connecting-rods and main bearings, though very small, is always downwards, and must be pro-

vided for in the clearance, and any attempt to minimize the waste room by restricting the area of the steam passages would give rise to back-pressure, and be worse than useless.

With a given diameter of cylinder and speed of piston, the percentage of clearance volume augments as the number of revolutions per minute. Thus a total clearance volume of 5 per cent., with a 36-inch stroke would be 20 per cent. in the case of a 9-inch stroke with identical proportions.

The low-pressure piston, in order to effectually balance the smaller piston of the high-pressure cylinder, is usually a steel stamping, and owing to its conical form may be of very light construction. Other things being equal, the fewer parts there are in a piston the better; hence, a solid piston body, having the rings sprung in, is, in itself, preferable to one in which a junk-ring is employed, where there is not only the possibility of the nuts securing the latter becoming loose, but the additional weight involved by this construction.

The conditions in high-speed engines, especially with high steam pressures and superheat, are rather exacting in regard to pistons and piston valves. For instance, the ordinary Ramsbottom ring cannot be employed unless with a follower or junk-ring, on account of its tendency to wear slack sideways. The word "clattering" aptly describes the characteristic sound of slack piston-rings. The Rowen piston, largely used, consists of a pair of concentric cast-iron rings, sprung into a solid piston, backed up by a waved flat steel spring.

Another waved or corrugated spring is placed between the two rings, giving lateral pressure, and taking up any side-play arising from wear. In the Buckley piston the functions of these separate springs are fulfilled by a pair of coiled springs of peculiar section, which at once back up the rings and press them sideways. Buckley's rings possess another advantage in that their expansion can be kept within any desired limit by the "locking-piece" which restrains the circumferential movement of the ring. A tight piston in a high-speed engine, with its seven or eight hundred reversals of motion per second, is a thing to be avoided at all cost. Hence the "limited expansion" ring, which can be allowed to expand until the cylinder and rings are worn to a polished surface, and then fixed at that point, when little more wear ensues for long periods. The follower plate or "junk-ring" is necessary, however, in all such pistons.

Piston valves may, in large sizes, be of very much the same construction as the main piston as regards the packing-rings. In cases where the loose-fitting valve liners mentioned are fitted, a simpler form of ring may be used with advantage. There being no tendency for the irregular expansion of the cylinder body to "nip" the liner, entirely solid rings, carefully ground to a dead fit, may be used. The influx of hot steam expands rings and liner equally, and the fit is preserved.

These rings, of which there is only one at each end of the piston valve, are an accurate, but easy, fit between the flanges of the latter, which are turned to a somewhat less diameter than the bore, the rings being thus free to adapt themselves to slight errors in the centrality or movement of the valve spindle. The valve itself is screwed tightly up to a fixed collar on the spindle, the adjustment or "setting" of the valve being effected by inserting solid washers or distance pieces of suitable depth above or below the valve, the usual system of fitting this valve between double lock-nuts upon a screwed spindle being inadmissible in these engines.

These piston valve rings being solid, *i. e.,* uncut, cannot, of course, be sprung in between the flanges, and junk-rings are necessary. These are secured to the valve body by a circle of studs, and not by the nuts

and collars of the spindle. The studs used for this purpose should have square holes in the junk-ring, to avoid the possibility of coming adrift. If the nuts are pulled down hard and "split-pinned," the probabilities are in favour of the whole working as one piece until it becomes necessary to let the junk-rings up a little to compensate for wear. Complexities in piston valves are to be deprecated, and the one described is cheap and reliable.

New solid rings can be fitted with little delay when required, making the valve practically equal to new again. It should be borne in mind, however, that solid rings cannot be successfully used, except in conjunction with the free-fitting liners already described.

The piston-rod and crosshead block are in one forging. The upper end of the rod is formed with a steep taper when it passes through the piston, and is secured by a large nut through which a split pin passes.

The taper of the piston and rod is an absolute dead fit, and is reinforced by a shoulder on the rod. The crosshead block formed on the end of the piston-rod is furnishd with cast-iron slippers, secured by set screws, a transverse feather or key on the back of each slipper-plate fitting a corresponding groove planed across the block. The latter is formed into a jaw, and a plain steel cap is secured by two long bolts, not studs, passing through the block with heads above, and lock nuts below. In passing, it should be noted that as far as possible all bolts should be turned down to a diameter corresponding to that of the threads, to secure equal stressing throughout the material, a short collared portion being left wherever required for fitting the hole of the full diameter. Within the jaw is a plain split bush, the upper half circular, the lower half flat, externally, fitted metal to metal. This bush should be of hard brass, or phosphor-bronze, unlined, on account of the heat conducted through the piston-rod. The connecting rod, though in reality of ample length for the stroke of the engine, looks almost absurdly short owing to its massive proportions. The upper end is constructed as a short fork, with the pin forced or shrunk in, and this form of joint, with its single plain bearing in the crosshead, is absolutely the best, and very nearly the cheapest to make, if properly handled, of all the types which have been tried for this class of engine. With the system of forced lubrication to be described presently, it may be relied upon not to give trouble. The large end is a flat foot with a steel cap and bolts passing through a pair of babbitt-lined bearings.

Very large and very broad these are, but as light as strength will allow. The nuts are at the bottom, but are not intended ever to feel the spanner. The bolt is turned from above by the head and screws into the nut, which is prevented from turning round by a projection on the cap.

The bolt itself is secured from turning by a small jam-screw, tapped into the connecting rod foot at right angles. The importance of reliable fastenings in the reciprocating parts is brought home to us at every step, and all these little careful arrangements are the outcome of experience and are to be found with little variation in the engines of all reputable makers.

Leaving the main reciprocating parts, we come to the valve motion. Here again absolute simplicity reigns. The eccentrics are usually fixed, that is, not adjustable, and set for a cut-off of 50 to 70 per cent. of the stroke. A broad, flat groove in the sheave and a plain strap, carefully locked, lined with white metal, and secured to the rod by a T-end is the design most generally adopted.

All attempts at automatic link gear in engines of this class have practically failed in the long run—or perhaps one should say in the long runs. The rod is fork-ended, and is a min-

iature copy of the connecting-rod small end. The hardened steel plunger into which the valve spindle is screwed passes through a bushed cast-iron guide in the top of the casing, fitted with a gland and recess for packing in the same way as the piston rods, and for the same reason,—to keep the oil in.

The throttle valve, contained in a circular box, bolted to the steam-chest, is of two general forms, the one perhaps most commonly used being practically the Cornish double-beat equilibrium valve, too well known to need description. The other consists of a flat cast-iron ring, raised and lowered by the action of the governor within a ported liner, after the manner of a piston.

If it were not that this liner and ring wear upon each other, this form of equilibrium valve would be nearly perfect; as it is, they can be renewed very cheaply, the liner being simply dropped into place and held up by a single set-screw, or even a strong spiral spring, a copper or asbestos ring making the joint with the valve-box in exactly the same manner as the piston-valve liners are fitted. The double-seated or Cornish valve is not under the same disability as regards wear, and with occasional refitting may last as long as the engine.

The governor now almost invariably used leaves nothing to be desired on the score of simplicity. It consists of a malleable-iron or cast-steel head, mounted upon a short prolongation of the crankshaft, turned down to small diameter. To this head are pivoted two short bell-cranked arms carrying the weights,—generally small discs of steel, or sometimes lead—at one extremity, and at the other engaging with a sliding collar on the spindle. Hooked on between the two weights, and resisting their centrifugal effort, is a tension-spring of suitable strength in relation to the weights and the rate of revolution. The sliding collar, in its turn, actuates a much larger right angle or bell-crank lever which connects with the equilibrium valve.

Means of adjustment for varying the speed of the engine are provided in the shape of a spiral spring encircling the governor rod, and more or less compressed by a small hand wheel running on a screw formed on the rod.

This adjusting spring acts in opposition to the governor spring, and is capable of effecting a useful amount of variation in the speed without appreciably disturbing the sensitiveness of the governing.

We now come to the oil-circulating system, the peculiar and essential feature of these engines. The bottom of the bed, as already mentioned, slopes downwards from both ends to the center, forming a sump or pocket, in which lies horizontally the gauze-protected intake, or strainer, of the oil-pump. This pump, upon which so much depends, is simple, even rudimentary, in design, possessing neither valves nor gland, and yet it may be relied on to deliver its oil under pressure for months at a time without a stop, at speeds which would disable almost any pump of usual construction in a very short time.

The idea of the oscillating valveless oil pump is probably derived from the cylinder of a toy steam engine, but instead of two flat faces in sliding contact, the lower part of the barrel is formed into a circular bearing in halves like a connecting rod end. The pin or trunnion which is encircled by this bearing is hollow, and divided internally by a longitudinal partition, one space being in communication with the suction, the other with the delivery. The plunger being coupled to one of the main eccentric straps, oscillates the barrel upon the trunnion, and thus brings a port in the bottom of the barrel alternately into coincidence with the ports cut through the surface of the trunnion into the suction and delivery spaces, respectively.

The oil is forced under a pressure of 10 to 20 pounds per square inch,

as regulated by an overflow cock, into an air vessel or chamber, from which it is distributed by iron pipes to the main bearings, thence by holes drilled through the solid material of the crankshaft, to the throw journals. Lubricating these in passing, the oil pursues its way either through a hole drilled up through the center of each connecting-rod, or by a small tube laid alongside the rod to the small end, thence to the crosshead slides. The eccentric straps receive this supply from a hole drilled radially through the sheave, meeting the main artery in the crankshaft, and from the strap, the joint-pin and the valve-plunger guide are reached, either by a hollow eccentric rod or by an external tube.

Through each and all of these rapidly moving parts, the oil streams unceasingly, interposing its strong pressure between the surfaces of the bearings, effectually separating them from actual metallic contact, and thus protecting them from wear indefinitely. This is the crowning excellence of the modern high-speed engine.

Part II., to appear in the September issue, will be made up of illustrations and particulars of the several prominent makes of engines of the class here considered.

FACTORY FIRE DRILLS

By H. F. J. Porter

IT should not require much argument to satisfy a reasoning mind that the better adapted the surrounding conditions are for any specific purpose, the more readily the desired results can be obtained, and the better those results will ultimately be. Accordingly, modern factory buildings are constructed with special adaptation to the needs of manufacture of the product in hand in each case. The attempt to adjust an old factory building to the requirements of an enterprise other than that for which it was originally intended is like any other makeshift,—unsatisfactory,—and ends usually in failure.

Unfortunately many factory buildings, especially those located in cities, are old and poorly suited to the service to which they are now put. These old buildings are too crude in their construction to be modified to meet the new conditions resulting from changes which have taken place in recent years in methods of manufacture, in sanitary appliances, etc. The changes that take place in adjoining property also affect the light, heat and fire risk of the older buildings.

Any manufacturing company which invites and assembles large numbers of human beings within the confines of its property for purposes of its own, in the nature of manufacture or otherwise, assumes certain obligations, some of which are covered by the laws of the land as well as of the community in which it is located, and others which may be either of a business character or of a moral nature. Some of these obligations are that the buildings occupied shall be safe in construction and in the loca-

A FIRE DRILL

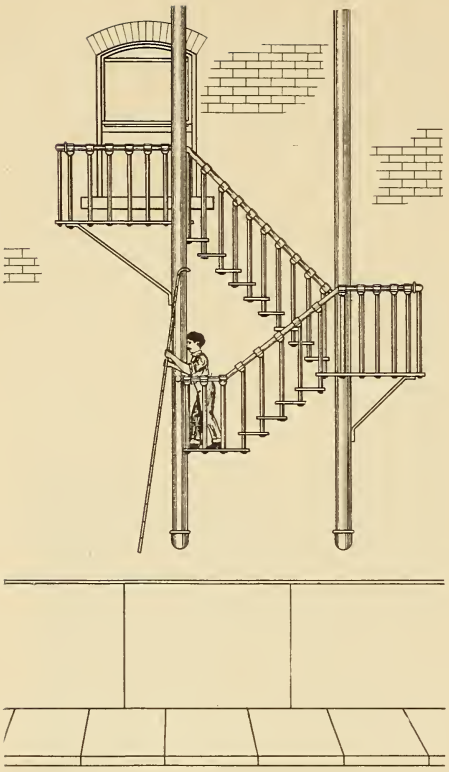


FIG. 1.—OLD FIRE ESCAPE. LADDER STOWED AWAY

tion and arrangement of the power plant and machinery. They must have modern sanitary appliances, proper water supply, and adequate fire protection.

All dangerous occupations must be accompanied by suitable precautions and safeguards. If good work is expected from the employees, the light under which they perform their work must be sufficient, and the temperature and conditions pertaining to their physical welfare must be considered, for an employee can do better work when comfortable than when uncomfortable.

Mental comfort or peace of mind is also an important attribute of the worker, and the intelligent manager is careful to see that his employees are free from the harassing accompaniments of favoritism, unfair foremen, threats of losing position, reduction of wages, etc. Security from accident is sure to give relief of mind, and the knowledge of the family at home that the husband or child is safe while at work has its reactive effect on the state of mind of the worker himself.

One of the greatest responsibilities assumed by a company is that of the safety of its employees in case of fire. Legal obligations in this regard do not cease altogether by the application of fire escapes to the exterior of the building, by the introduction of a sprinkler system, by the placing of buckets of water and hand fire extinguishers in exposed and convenient places, and the supply of hose attached to risers filled with water under pressure. It is still necessary to keep the fire escapes unobstructed, to see that the other apparatus is kept in working order, and to arrange that some one is instructed in its use. How many fac-

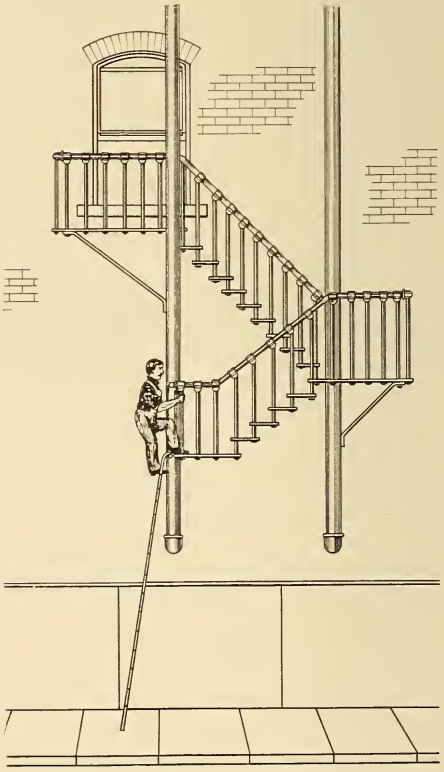


FIG. 2.—HERE THE LADDER IS SHOWN LOWERED

tories live up to these requirements?

But the moral obligation to take such other precautions as have been found necessary to preserve life in case of fire goes still further, for statistics show that there are more serious results from accidents due to panic in case of fire than are occasioned by the fire itself. In fact, so general is the recognition of the danger inherent in the mere assembly of people in buildings, that in public schools and the best organized factories fire drills are now voluntarily established and legislation is being strongly advocated in many places that such precautions be legally and rigidly enforced.

Particularly important are provisions of this kind when several hundred employees of both sexes are engaged at work, whether closely assembled or scattered widely over a large area, for it is well known that under circumstances of intense excitement men lose their reason, and in their desperation to seek safety forget or disregard the inability of women to cope with emergencies.

In a recent experience with a factory which the writer was engaged to reorganize, realizing the responsibilities resting upon the company and upon himself as temporary director of its interests, and knowing the inflammatory character, not only of the factory building itself, but of the buildings which surrounded it, and also the inadequacy of the avenues of escape from within in case of fire, he at once instituted a fire drill, complete in every detail. At the sound of the whistle not only was a corps of firemen required to assemble at the location of the supposed fire and go through the manœuvers of extinguishing it by unreeling the hose, etc., but under a well-organized system every employee was quietly, but hurriedly, marched from the building to the street. At times, also, water under full pressure was put upon the hose.

The first time this complete drill was carried out and the employees descended to the street by means of the fire escapes on the exterior of the building, the fact was discovered that the devices at the first floor for connecting these escapes with the street were wholly inadequate for the purpose. The attention of the lessors of the building being called to this condition of affairs, it was promptly remedied, and subsequent fire drills reduced the time of evacuation from more than seven to less than three minutes. This difference of over five minutes would, in case of a rapidly burning fire or a slow fire producing a heavy smoke, be the means of saving many lives.

The accompanying illustrations will serve to make plain the change referred to. Figs. 1 to 4 show the lowest landing of the fire escapes above the street. Figs. 1 and 2 show the old arrangement of the ladder at this landing which, when out of service, was raised from the street and hung up out of the way. In case of fire, this ladder had to be lowered and adjusted in place by the first person who happened to reach the spot, while many others, all probably under great excitement, were running down the stairs and crowding up behind him. The wonder under such circumstances would be that these would not push him off into the street before he had succeeded in accomplishing his purpose and turned around in order to go down.

The action of turning and going down backwards when many people were pushing and crowding from behind was shown to be utterly impossible of execution. Those in front would simply have been pushed off onto the pavement and those immediately behind would have fallen on them. It is remarkable how many "escapes" of this type can be seen everywhere. They are regarded as the standard type.

Figs. 3 and 4 show the alteration made which allowed those who first arrived upon the landing to run out upon the suspended ladder and de-

scend to the sidewalk by virtue of their weight. Those following simply continued to run downstairs until they reached the ground. These sketches have been given to the Industrial Section of the Civic Federation and to the Institute for Social Service, both of which organizations make public through municipal boards and other similar organizations improvements of this kind, in the hope of their general adoption. There is no patent on the improvement and it can be made by any one who has facilities for working iron.

The writer has communicated with a large number of representative factories for the purpose of securing copies of their fire drill rules, but has so far failed to find any factory which includes in its drill a complete exodus of employees to the street. For the modern factory building which is fireproof and offers little probability of a fire occurring either within or without the premises, it is often thought unnecessary to prepare for an emergency necessitating the emptying of the factory of its occupants. In the general run of factory buildings, however, the opposite conditions exist and provisions should undoubtedly be made so that in case of necessity the employees can be marshalled out of the building in order and without loss of time. And it is the unexpected that happens and that should be provided for.

Only a few months ago a fire, kindled under a portable boiler in a city street, emitted considerable smoke which, entering the windows of a nearby corset factory, caused a panic among the girls employed, who, in their effort to escape from the building down a narrow stairway, seriously injured several of their own number. Some of them fainted and were trampled upon by others.

On the introduction of a fire drill in a factory where women are employed, no matter how well understood it may be that the sounding of whistle or bell at a certain time will indicate, not that there is a fire, but that a drill is to be carried out, the writer has found it an almost universal occurrence that several of the women will faint through mental association of the fire whistle or bell with danger. It is only by repeated drills that the effect of this association wears off, yet it should be the duty of certain persons in every fire drill to go carefully into every room and make a round of the seats where girls have been working to see that none have collapsed.

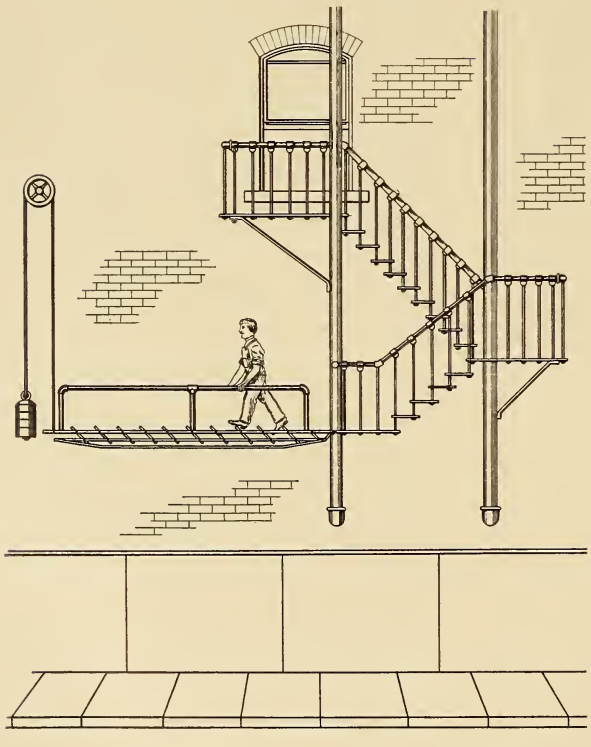


FIG. 3.—IMPROVED FIRE ESCAPE. LADDER STOWED AWAY

The working-out of a complete fire drill is something that must be done by some one conversant

not only with such matters but with the requirements of the conditions surrounding each situation. There are, however, a number of precautions, general in their nature, which should be a part of the rules of every well-organized factory. These are:—

1.—Red lights throughout the building to denote location of fire escapes.

2.—Foremen must carry with them, or have hung in a conspicuous place from which it can readily be taken, a list of their employees, so that, after leaving the building and arriving in the street, they can call the roll and see that all are present.

3.—Employees leaving the building with departments other than their own, upon reaching the street, must report immediately to their own foreman.

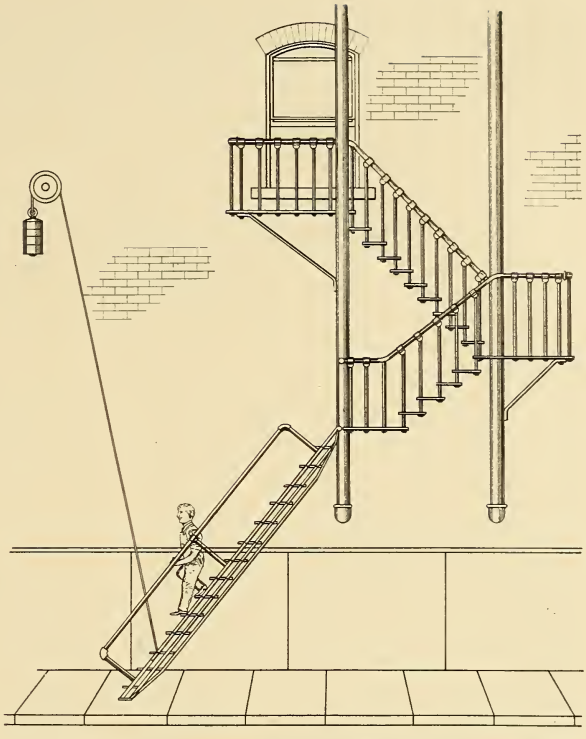


FIG. 4.—WITH THE IMPROVED FIRE ESCAPE, THE LADDER IS LOWERED BY THE WEIGHT OF THE MAN

4.—Each foreman must appoint two fire leaders in his department, and see that they are instructed in their duties.

5.—It will be the duty of any one using a gas flame to turn it out before joining the leader.

6.—Incipient fires must be attacked at once by means of extinguishers in hand tubes, hung in conspicuous places. Fire caused by the igniting of oil or benzine must be put out by the use of such hand extinguishers only, instead of water. The latter simply causes such a fire to spread.

7.—In the case of a fire accompanied by considerable smoke, employees should tie a wet handkerchief over nose and mouth and, as the air close to the floor is most free from smoke, crawl on hands and knees to the nearest exit.

Employees who understand that such rules are introduced into the discipline of the place for their own safety will be only too glad to aid in their enforcement. The company which takes upon itself the establishment of a fire drill, carrying it out in its entirety once a month by not only testing the fire-extinguishing apparatus thoroughly, putting the hose under pressure, etc., but by taking the occupants of the building out upon the street will, even if it has done nothing else of a sociological nature for its employees, immediately produce the effect upon their minds that their interests are being subserved and will thus secure benefits in return from the desire on their part to reciprocate.

The establishment that possesses the interest of its employees in its welfare is far ahead of its competitors who have not secured that valuable possession; but in order to se-

cure it, evidence must be given by the employers themselves that they take an interest in the welfare of their people. There can be no more striking evidence of such interest than the desire to protect their lives.

THE ELECTRICAL MEASUREMENT OF HIGH TEMPERATURES

By H. S. Knowlton

FOR more than half a century few scientific problems of greater difficulty or more practical importance have occupied the attention of physicists and metallurgists than the measurement of high temperatures. Accurate knowledge of the temperature prevailing in many kinds of furnace work is one of the first essentials of that systematic analysis of cause and effect which leads to lasting success. In steel works, glass and porcelain manufactories, and in the production of various chemicals on a commercial scale, something more is required than approximate information based upon the uncertainties of personal judgment. Such industrial processes must be subjected to rigorous technical investigation in order that the depreciation of the product may be avoided, the heating and cooling properly regulated, fuel economized, and needless waste eliminated.

Almost every thermal phenomenon has been utilized for temperature measurement. Innumerable attempts have been made to determine high temperatures by experiments upon the expansion of solids, liquids, and gases, vapour tension, dissociation, fusion, ebullition and specific heat, tests upon conduction, radiation, viscosity, spectrophotometry, colour, rotary polarization, and acoustics. The mercurial pyrometer reading to 970 degrees F., the metallic pyrometer carrying the range of measurement to 1500 degrees, the water pyrometer indicating 2700 degrees, and the optical pyrometer with a maximum reading of about 3600 degrees, all exemplify the application of some of these phenomena in instruments now upon the market for commercial service.

Valuable as have been the researches of the past with some of the apparatus based upon the mechanical effects of heat, and important as such methods are to-day in the laboratory, there is no question that the thermo-electric pyrometer is by far the most promising and generally satisfactory means of determining high temperatures for industrial work as well as for many measurements in scientific research.

The Le Chatelier pyrometer probably represents the latest development of apparatus now employed for the electrical measurement of high temperatures. It consists of a thermo-electric couple and a D'Arsonval galvanometer. One of the wires composing the couple is of pure platinum and the other of platinum alloyed with 10 per cent. rhodium, both of which are perfectly homogeneous. When the couple is inserted in the furnace or oven of which the temperature is to be measured, an electromotive force is produced, and if the couple is connected with a galvanometer a deflection is made upon the scale from which the temperature is readily reduced. This electromotive force, in the case of the platinum-rhodium couple, varies from 565 micro-volts at 100 degrees C. to 15,100 micro-volts at 1500 degrees C.

The pyrometer is consequently capable of measuring temperatures approaching the melting point of platinum, having a range of from 200 degrees F. to 3000 degrees F., but its special advantages are found in the measurement of such high temperatures as are met in the manufacture and treatment of metals, chemicals, ceramic ware, etc. The melting points of lead, zinc, silver, gold, and palladium, all lie within the range of the electrical pyrometer.

In comparison with other apparatus for the industrial measurement of high temperatures, the advantages of the thermo-electric method are noteworthy. The apparatus is almost instantaneous in its indications, 5 seconds being a sufficient time for which to subject the couple to any stationary temperature. If desired, the couple may be left permanently in the furnace or oven, indicating at all times the exact temperature and thus enabling the operator to keep a close record of the variations.

The metals which compose the couple are unaffected by gases, and do not become oxidized or react on each other at high temperatures; nor are their thermo-electric properties altered by rough usage or bends. New elements may readily be substituted for old couples, and as the galvanometer scale reads in millimeters, a simple standardization curve is all that is needed to convert the deflections into temperatures. An important advantage of the thermo-electric pyrometer lies in its being available to measure temperatures under all pressures, as the changes in thermo-electric property under pressure variation are negligible in comparison with the thermal sensitiveness of the couple.

The instrument is capable also of measuring temperature where the dimensions of the hot space scarcely exceed a physical point. Hence small zones of constant temperature and relatively small apparatus for heating are sufficient for thermal comparisons of relatively great accuracy. The upper limit of temperature measurement lies much above the melting point of platinum; for, by employing refractory alloys of platinum, iridium and rhodium, and enclosing wires of these metals in tubes of calcined lime, powerful thermo-electric phenomena are obtained, even when the contents of the tubes are fused. The electromotive forces of suitable thermo couples are stated by Barrus to be easily measurable with an accuracy of 1 in 1000, and with almost the same accuracy may the indications observed at the beginning of any year be compared with those at the beginning of the next or at any other subsequent time. Consequently the secular errors of a thermo-electric pyrometer need not be relatively larger than those of a mercurial thermometer.

The idea held in some quarters that the electrical pyrometer is too delicate an instrument for commercial service is a mistake. One of its greatest advantages lies in the possibility of reading its indications at any reasonable distance from the furnace. A simple pair of stout copper wires will carry the temperature story anywhere in an industrial establishment.

One form of thermo-electric pyrometer now on the market is equipped with a portable galvanometer and porcelain couple manipulator, which makes commercial measurements as easy as the determination of potentials with a direct-reading voltmeter. Doubtless the setting up of a pyrometer of the D'Arsonval type is a task for a trained employee, but once it is in position, the mere reading can be done by any foreman after a little explanation.

When important automatic records of high temperature variation are desired, the use of the reflecting galvanometer in a darkened room in connection with a moving strip of photographic paper offers a means of preserving the most delicate fluctuations.

COMMERCIAL MOTOR VEHICLES

By J. F. Gairns

PART II.—PETROL, ALCOHOL AND ELECTRIC VEHICLES

Part I., in the July number, was devoted to "Steam Motor Vehicles"

IT has already been remarked that, for the heavier types of commercial motor vehicles, steam is the most usual motive power, particularly in British practice, whereas for the lighter vehicles, which are in many cases merely developments of the ordinary private cars, the internal combustion engine is generally employed. In the following pages a representative selection of motor vans, lorries and like vehicles, operated by petrol, will be described. The word "petrol" will here be used as including gasoline, paraffin, petroleum, alcohol, and like fluids used for explosive motors. It will be noticed that the vehicles described under this heading are fairly cosmopolitan in character, for in all the principal countries of the world they are both built and used, whereas the building of heavy steam vehicles is more especially a British industry.

The Wolseley Tool & Motor Car Company, Ltd., of Birmingham, England, is well to the fore in the production of vehicles of the kind under notice, and some of their cars will first receive attention. In Fig. 23 a 2-ton wagon built by this firm is shown, and while the general features are well presented by the illustration, the following notes as to the construction and arrangement of the engine and other parts will be of interest.

The platform provides an area of 50 square feet for the carriage of goods, and the vehicle, while designed for a load of 2 tons, is capable of dealing with maximum loads of 3 tons, the weight without load being about $2\frac{1}{2}$ tons. The engine is horizontally arranged so that the driver's seat can be placed well

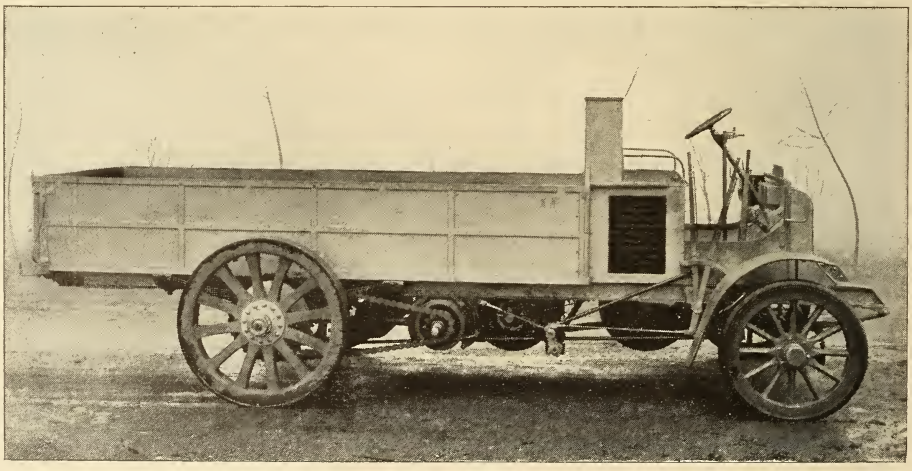


FIG. 23.—A 2-TON MOTOR WAGON BUILT BY THE WOLSELEY TOOL & MOTOR CAR COMPANY, LTD., BIRMINGHAM, ENGLAND

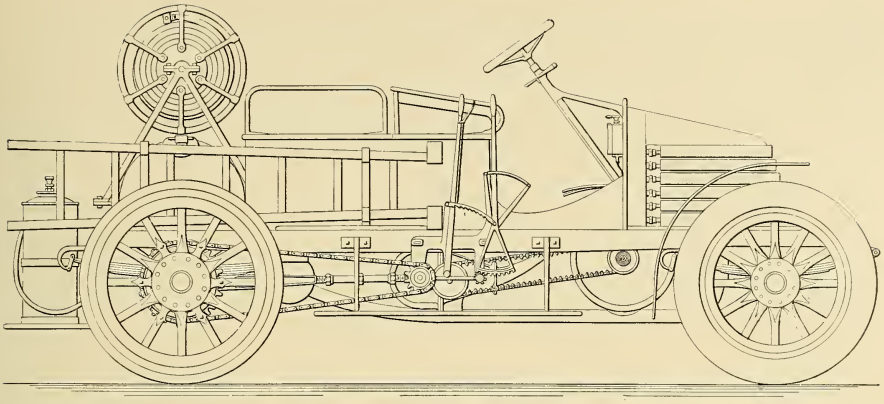


FIG. 24.—A 12-H. P. MOTOR-PROPELLED CHEMICAL FIRE ENGINE BUILT BY THE WOLSELEY TOOL & MOTOR CAR COMPANY, LTD.

forward, and is of the usual "Wolseley" type with two horizontal cylinders, 6-inch diameter and 7-inch stroke, developing 20 B. H. P. at 600 revolutions per minute.

Transmission is effected by "Renold" silent chains, and the gearing is all enclosed, running in grease. Sliding gears are employed, giving forward speeds of $2\frac{1}{2}$, 5, 8 and 13 miles an hour, and one reverse speed of 5 miles an hour, all the changes being made by one lever. The rear road wheels are driven independently by roller chains from the ends of the differential shafts in the gear box. Three independent brakes are fitted, and the pedal brake operates on a water-cooled drum on the high-speed countershaft, while the side lever brake acts on two drums attached to the sprockets on the road wheels. The engine is controlled by a hand throttle, and the electric ignition is timed by a lever on the control column. Worm steering gear is em-

FIG. 25.—A 2-TON PETROL BOX VAN BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LTD., LONDON

ployed. The radiator is fan-cooled and is located at the side of the driver's seat as shown. An exhaust silencer is provided. The petrol tank has a capacity of 10 gallons,—sufficient for a run of about 60 miles with full load.

The van illustrated is provided with a cover which can be readily fitted when required for use as a covered van. Similar vehicles are built, fitted in various ways as regards superstructure. Of these may be mentioned mail vans, several of which are in use in the British mail service; tipping wagons, adapted for contractors' and municipal purposes; ambulance vans; fire engines both large and small, and tram cars.

The drawing reproduced in Fig. 24 represents a 12-H. P. chemical fire engine recently supplied by the Wolseley Company, and this illustration, apart from its individual interest, well sets forth the main features of the arrangement of the Wolseley vehicles, except that the engine in this case is vertically arranged within the front bonnet and the radiator is differently fitted.

Of late, the well-known firm of John I. Thornycroft & Co., Ltd., of London, has extended its business into the field of petrol-driven commercial vehicles, and in Fig. 25 a box van built by them is shown. This is adapted to deal with loads up to 2 tons upon a maximum gradient of 1 in 10 on ordinary roads, the normal speed being about 10 miles an hour. The engine is of the four-cylinder type, developing 20 H. P. at normal speed, the whole of the engine and the engine gearing being enclosed in an oil-tight case and lubricated by the splash method. Water-cooling is employed, a rotary geared pump being used for circulating the water.

The change speed gears give forward speeds of $2\frac{1}{2}$, 5 and 10 miles an hour, and a reverse speed of $2\frac{1}{2}$ miles an hour. The final transmission from the gear box to the back axle is by means of a "Renold" roller chain. Vehicles of corresponding type fitted

FIG. 26.—A 2-TON OPEN PETROL VAN BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LTD.

FIG. 27.—A PETROL TRACTION ENGINE HAULING A TRAILER. BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LTD.

FIG. 28.—A 30-CWT. LIGHT PLATFORM LORRY BUILT BY THE LANCASHIRE STEAM MOTOR COMPANY, LTD., LEYLAND

with various styles of superstructure are built, adapted for loads up to about 5 tons, though usually 3 tons is about the maximum provided for. Fig. 26 illustrates a similar open van built by the same firm and used for mineral water traffic.

As in the case of the steam vehicles described in the July number, a study of practice involves the consideration of "tractor" vehicles by which all the load is hauled in trailers, and Fig. 27 an interesting adaptation of the petrol engine as a light traction engine or "tractor," is illustrated.

It will be noticed that the parts are arranged so as to give the general appearance of an ordinary traction engine, though this is not of course necessary. As shown, the tractor is employed hauling a brewer's trailer, the attached vehicle being merely an ordinary brewer's dray having the shaft pole removed and a draught coupling fitted. It is for such circumstances, to provide for the use or non-use of mechanical motive power

at will with the same vehicles, that the advantage of a separate tractor is realized, otherwise the motor van is preferably and more generally employed. Provision is also made for the use of the tractor to be used as a portable engine to drive other machines.

In construction, the tractor comprises the same elements as the ordinary vehicle, but large fuel capacity is provided,—usually for about 60 miles, and this can be increased for a further 50 miles by carrying an additional tank in the rear locker. The gross weight of the tractor is about 3 tons, while it can deal with loads of about 6½ tons on hard macadam roads with a maximum grade of 1 in 8. Spuds can be fitted on the driving wheels for use on soft ground.

A two-cylinder horizontal engine developing 25 brake H. P. is employed. The gearing clutches are of the multiple friction disc type, completely encased and running in oil. Bevel gearing is employed for the first transmission, and a "Renold" chain to the differential gear on the back axle. A winding drum is fitted for hauling the tractor or its load out of difficult positions. The gear speeds are 1½, 4 and 8 miles an hour, and can be obtained either forward or reverse.

As in the case of the firm whose productions have just been described, several other firms whose principal business is done in connection with steam vehicles have recently introduced petrol vehicles, and in Fig. 28 a 30-cwt. light platform lorry, built by the Lancashire Steam Motor Company, Ltd., is shown. In general construction it corresponds to ordinary motor vehicle design, there being included only a few special features characteristic of the builders' practice.

Similarly in Fig. 32, a light delivery van built by the Bristol Wagon & Carriage Works Company, Ltd., is shown. These vehicles are built in several sizes, generally to deal with loads less than those for which even the smallest of their steam vehicles are designed. At this juncture it may be mentioned that most of the firms concerned with ordinary motor car practice build these light delivery vans. In most cases they correspond to the private cars except in the nature of the body fitted, and that only medium speeds are provided for.

The Beaufort Lorry Company is coming to the front in supplying petrol-operated lorries and like ve-

FIG. 29.—A LIGHT LORRY FOR MINERAL WATER TRAFFIC. BUILT BY THE BEAUFORT LORRY COMPANY, LONDON

FIG. 30.—LIGHT DELIVERY (ARGYEL) VAN BUILT BY THE HOZIER ENGINEERING COMPANY, LTD., GLASGOW

FIG. 31.—A 3-TON COVERED VAN BUILT BY MESSRS. GLOVER BROS., LTD., LONDON

FIG. 32.—LIGHT DELIVERY VAN BUILT BY THE BRISTOL WAGON & CARRIAGE WORKS COMPANY, LTD., BRISTOL

hicles, and in Fig. 29 one of their vehicles used for mineral water traffic is illustrated. This vehicle is really a development of business done with char-a-bancs, wagonettes and omnibuses up to about 2½-ton loads, but is only adapted to carry about 1½ tons, somewhat higher speed than is usual with the heavier vehicles being provided for.

The Hozier Engineering Company, Ltd., of Glasgow, are introducing the light delivery van illustrated in Fig. 30. A two-cylinder, 13-H. P. engine is employed; this drives the vehicle by special clutches which admit of the speed being regulated without its being necessary to change the gear for momentary speed changes as are required when working through traffic, since the car can be driven at one mile per hour on the top gear. The gears provided, apart from the clutch arrangement referred to, permit of speeds of 4, 9 and 15 miles an hour. The vehicle illustrated is adapted for a load of about 16 cwt. Similarly, vehicles fitted with platform or open-van body are also built.

Until recently the firm of Glover Bros., Ltd., has been more concerned with horse-drawn vehicles, but they are now building motor-propelled vehicles, two of which are illustrated in Figs. 31 and 34, the one being a covered van and the other a flat lorry; both are adapted for loads up to 3 tons. A two-cylinder engine is employed, and the gearing provides for three forward speeds and one reverse speed actuated by one lever with a direct drive on top speed. The differential countershaft is separate from the gear box and is connected thereto by a slightly flexible joint so as to allow of play of the chassis on the springs over uneven roads or with variable loads. Side chains transmit power from the differential countershaft to the rear wheels.

A 1-ton delivery van built by Messrs. Dennis Bros., Ltd., of Guildford, is shown in Fig. 35. It is driven by a 14-H. P. slow-running automatically-governed engine with worm gear giving a direct drive at slow speed. This firm also build corresponding vans capable of dealing with 2-ton loads at fairly high speed.

Fig. 33 illustrates a 30-cwt. petrol

FIG. 33.—A 30-CWT. DELIVERY VAN BUILT BY THE THAMES ENGINEERING WORKS COMPANY, GREENWICH

van built by the Thames Engineering Works Company,—a firm whose steam vehicles have already received attention in Part I. of this article printed in the July number of this magazine. The van shown is driven by a two-cylinder engine, water-cooled, and provided with electric ignition; the gears are arranged for three forward speeds and one reverse speed. The car will run at speeds up to about 14 miles an hour, and can haul the full load up heavy gradients. The starting gear, seat, etc., are arranged well forward on the frames so as to allow for large load capacity.

So far, all the firms whose productions have been described are British, and the list of builders of vehicles of the kind under notice is by no means exhausted; indeed, there are many firms well known in the motor world whose work merits inclusion, but it is now time to deal with work done in other countries though necessarily somewhat briefly.

One of the best known American firms building petrol-driven commercial vehicles, is the Knox Automobile Company, of Springfield, Mass. Fig. 36 illustrates an open van built by this firm intended for a load of about 1¼ tons. The engine is operated by gasoline fuel, and an important feature of the Knox design is the use of air-cooling apparatus, water-cooling being dispensed with. In the ordinary way, two speeds forward and one reverse are provided for, and in the case of the van illustrated, the top speed is about 18 miles per hour. The two cylinders are arranged horizontally, and drive the cranked axle from opposite sides. Fans, one for each cylinder, are driven by belt gearing off the longitudinally arranged valve operating shaft. A rather curious feature of the air cooling is the provision of a very large number of corrugated pins projecting from the whole of the cylinder surfaces for heat radiation.

Fig. 37 shows a flat lorry of about the same power. This is usually supplied with a removable canvas roof which can readily be fitted and removed. Fig. 38 represents an open-work frame-covered van of similar dimensions to the previously described vehicles, and Fig. 39 illustrates a lighter constructed delivery van built

by the same firm. In the latter case the engine is of the single-cylinder type.

Considering now the productions of a few German firms, work done by the Neue Automobile Gesellschaft, a branch of the well-known Allgemeine Elektricitäs-Gesellschaft, will first receive attention.

Fig. 42 illustrates a heavy wagon designed for loads up to nearly 6 tons. A twin-cylinder vertical engine, developing 14 H. P. at 650 revolutions per minute, is fitted at the front of the car under the removable bonnet, and is cooled by a large surface cooler using only a small quantity of water in conjunction with a high-speed belt-driven fan; a centrifugal pump is employed for circulat-

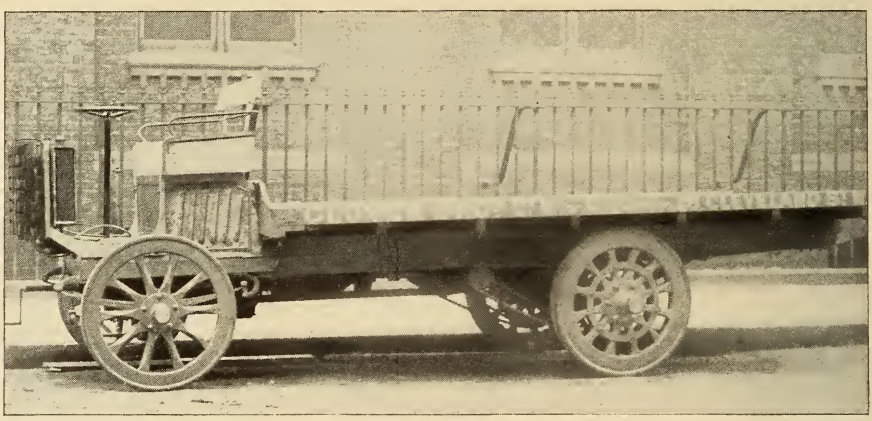


FIG. 34.—A 3-TON FLAT LORRY BUILT BY MESSRS. GLOVER BROS., LTD., LONDON

FIG. 35.—A DELIVERY VAN BUILT BY MESSRS. DENNIS BROS., LTD., GUILDFORD

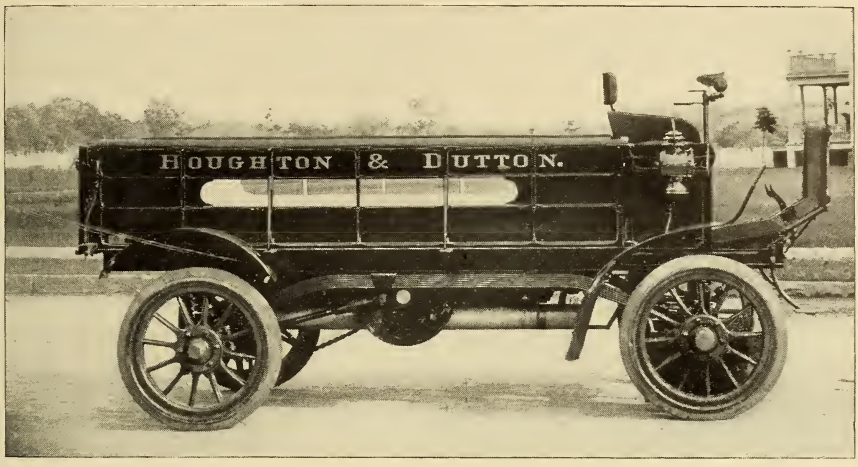


FIG. 36.—AN OPEN VAN BUILT BY THE KNOX AUTOMOBILE COMPANY, SPRINGFIELD, MASS., U. S. A.

ing the water. The engine is operated either by petrol or alcohol, and in the latter case a double carburetter is provided so that petrol can be used at starting, the alcohol being brought into use when the motor is sufficiently hot. The apparatus is automatic in action.

The fuel tanks are of sufficient capacity for from 65 to 95 miles. A throttle governor varies the fuel supply and ignition according to requirements, and a regulator enables the engine speed to be varied within wide limits. From the engine, power is transmitted by a friction clutch and shafting to the gear box, where three forward speeds ($1\frac{1}{4}$, $3\frac{1}{8}$ and $7\frac{1}{2}$ miles per hour) and two reverse speeds ($1\frac{1}{4}$ and 2 miles per hour) are arranged for, the final connection past the differential gearing being effected by chains to each of the rear road wheels. Similar lorries and vans fitted with various bodies to suit requirements are built to carry loads of

FIG. 37.—A FLAT LORRY BUILT BY THE KNOX AUTOMOBILE COMPANY

1½ to 2 tons, and 3 to 3½ tons, 6 and 10-H. P. motors being fitted in these respective cases.

Fig. 41 illustrates a motor train fitted by this firm, which represents an interesting and useful adaptation of motor traction. The leading vehicle is described as a tractor fitted with a 40-H. P. alcohol motor, but it also carries a portion of the load. The three vehicles together serve for the carriage of 20 tons.

The Berliner Motorwagen Fabrik is another German firm doing a large business in heavy commercial motor vehicles of various kinds. A very important part of their business is in connection with light delivery vans (see Fig. 40) capable of dealing with loads of about 1 ton. These vehicles are used very extensively in most German cities, some firms owning them in large numbers. One Berlin firm uses 55, and they have also been adopted for mail vans in Berlin and in London. Besides these lighter vans, heavy vehicles loading up to about 5 tons are built, many being employed in German and other government services; and omnibuses, etc., fitted with the same kind of chassis as is employed for the corresponding vans, are in extensive use.

A 5-ton lorry built by this firm is adapted for four forward speeds and one reverse. A four-cylinder motor running at 100 revolutions per minute is fitted in front, and power is transmitted by cone friction drums comprised in the speed gearing, and independently by chains to the rear wheels. Alcohol is used for the motor in general work, but petrol is employed for starting, and one automatic device ensures that before stopping, the petrol supply is placed in connection with the engine ready for starting again; when well under way the conversion from petrol to alcohol fuel also results automatically.

For the 2-ton vans a two-cylinder motor is used, but otherwise the mechanism corresponds to that already briefly described for the heavy vehicles. In the case of the light 1-ton vans, belt gearing and an ar-

FIG. 38.—AN OPEN FRAME COVERED VAN BUILT BY THE KNOX AUTOMOBILE COMPANY

FIG. 39.—LIGHT DELIVERY VAN BUILT BY THE KNOX AUTOMOBILE COMPANY, SPRINGFIELD, MASS., U. S. A.

FIG. 40.—A 1-TON PETROL OR ALCOHOL DELIVERY VAN BUILT BY THE BERLINER MOTORWAGEN FABRIK, BERLIN, GERMANY

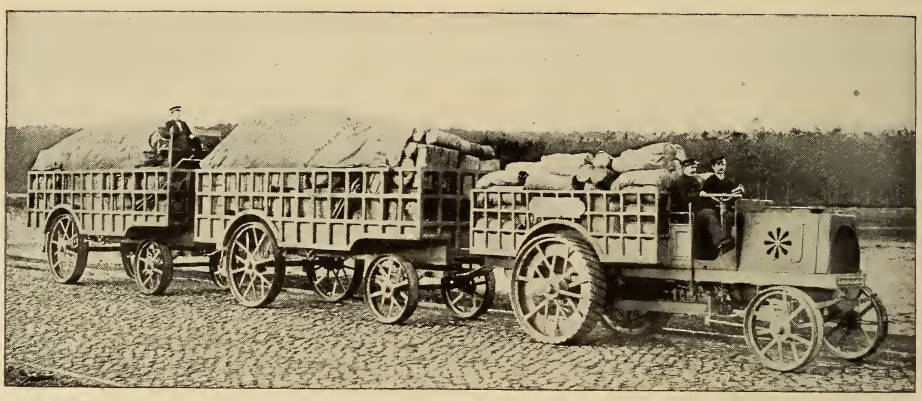


FIG. 41.—MOTOR TRACTOR AND TRAIN FOR A LOAD OF 20 TONS. BUILT BY THE NEUE AUTOMOBILE GESELLSCHAFT, BERLIN

FIG. 42.—A HEAVY MOTOR WAGON FOR LOADS UP TO 6 TONS. BUILT BY THE NEUE AUTOMOBILE GESELLSCHAFT

rangement of fast and loose pulleys is employed for the first power transmission, differential and belt gearing actuating the rear driving wheels. A 7-H. P., two-cylinder petrol or alcohol motor is employed.

Another German firm doing considerable business with small delivery vans is the Adler Fahrradwerke, Vormals Heinrich Kleyer, of Frankfort. Besides these, a number of firms generally associated with ordinary motor car work build small motor vans, and the same remarks apply to most other Continental countries. In France the principal firms doing business of this character are Messrs. Panhard & Levassor, of Paris, and the Aries Company. In Italy at least one firm recently introduced 1½-ton and 4-ton flat lorries.

Before concluding this article, reference will now be made to the design of heavy commercial vehicles operated electrically. Almost without exception this business is confined to the United States, for what electric vehicles are supplied for commercial use elsewhere are, as a rule, merely adaptations of the ordinary electric motor cars, a delivery van body being fitted instead of the usual body.

Figs. 43 and 45 illustrate respectively a heavy and light van operated electrically and supplied by the Electric Vehicle Company, of Hartford, Conn., U. S. A. For these vehicles the trade term "Columbia" is

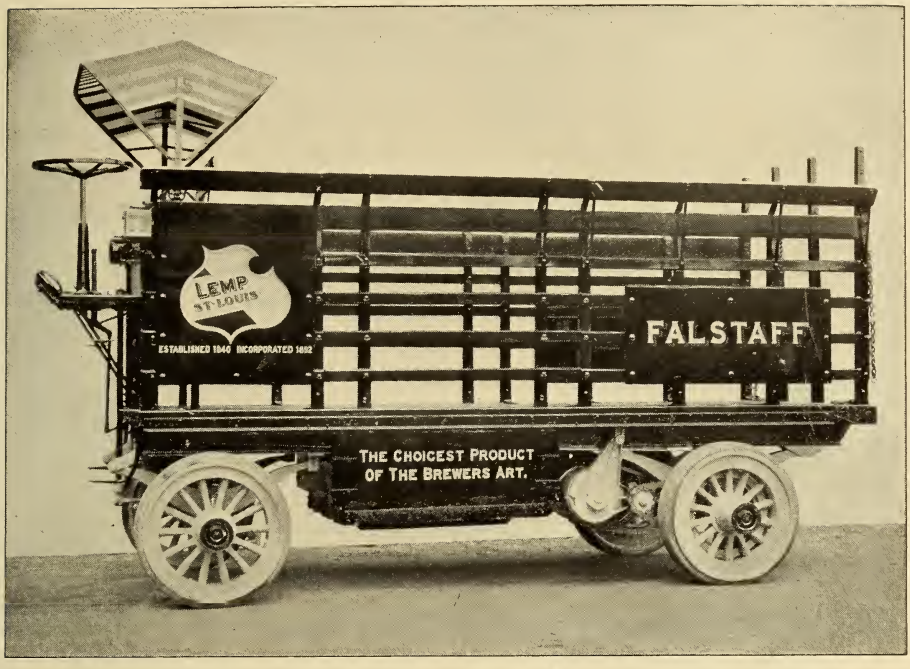


FIG. 43.—A 5-TON ELECTRIC VAN BUILT BY THE ELECTRIC VEHICLE COMPANY, HARTFORD, CONN., U. S. A.

FIG. 44.—MOTOR TRUCK BUILT FOR THE MICHIGAN STOVE COMPANY BY THE COMMERCIAL MOTOR VEHICLE COMPANY, DETROIT, MICHIGAN, U. S. A.

universally employed. The storage batteries are of the light weight lead type, and have formed the subject of extensive improvements in order to render them suitable for commercial

FIG. 45.—A 1-TON ELECTRIC OPEN VAN BUILT BY THE ELECTRIC VEHICLE COMPANY, HARTFORD, CONN., U. S. A.

use. The cars are supplied in sizes adapted for loads of from $\frac{1}{2}$ to about 4 tons, with various styles of bodies. The open van shown in Fig. 45 is one of a series supplied to the Adams Express Company for dealing with maximum loads of nearly 1 ton. Two motors are employed, connected to the driving wheels by double reduction gearing and separate chains, and a speed of 11 miles per hour with full load is provided for. The batteries are sufficient for a radius of 35 miles per charge. The brewer's van shown in Fig. 43 is intended for loads up to nearly 4 tons, and is a good representative example of practice with respect to the heavier vehicles.

The Commercial Motor Vehicle Company, of Detroit, Mich., is another American firm dealing with electric vans, and although the firm is of recent organization the work done by them is of particular interest. The special features of practice are principally the use of independent motors for each of the four wheels, and the special gearing employed for power transmission and to admit of steering the wheels, the motors moving with the wheels.

In Fig. 44 is illustrated what is claimed to be the largest and most powerful freight truck in the world, and this claim appears to be justified by the dimensions. The length is 23 feet, with an extreme width of 7 feet, and four $3\frac{1}{2}$-B. H. P. motors for driving, one motor for each wheel; all the wheels are adapted for steering movements. The weight is $7\frac{1}{4}$ tons with a battery of 80 cells having a capacity of 375 ampere-hours, and a load of over 9 tons can be carried. The speed provided for is 6 miles per hour. Corresponding

vehicles of other descriptions are also built, some of them of a special character, among which may be mentioned a flat lorry fitted with an electric crane to facilitate dealing with awkward loads.

Although much matter worthy of inclusion and of consideration of engineering features involved has been necessarily omitted from the foregoing, and although the writer does not pretend to have dealt with the work of every firm concerned with vehicles of the kind under notice, sufficient has been described to set forth the main principles of practice and to indicate the nature and character of motor vehicles provided for business purposes.

The writer has to acknowledge the very material assistance rendered him by the firms whose productions are described, both in the supply of information concerning their methods and practice, and in providing photographs and drawings of which only a selection is perforce utilized in this article.

MACHINE SHOP ROOFS

By John E. Sweet

PRIMARILY, roofs are for the purpose of protecting buildings and their occupants from the elements, and in that roofs for machine shops are not different from roofs of other buildings; but for the machine shop the roofs may help to do many things besides, and while to do these things may call for a modification of the regulation style and even in some cases add to the cost, the gain will more than justify the modification. Assume, for example, no question can arise except,—Is the usual form of construction the best and most economical?

Depending upon the span, the trusses are placed 20 or 30 feet apart. Whether it has been determined mathematically that a certain ratio exists which requires the least material, or whether these spacings have been hit upon to meet available material, there is this against the plan:—It calls for purlines, rafters and planking where the roof is of

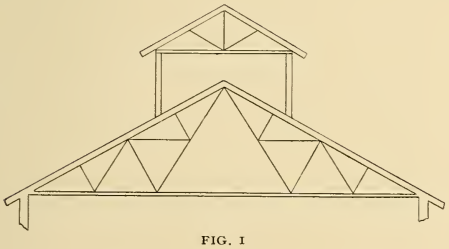


FIG. 1

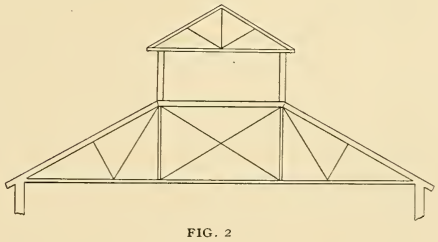


FIG. 2

a shop of the prevailing type,—a central bay for the traveling cranes and wings and galleries each side. The roof over the central bay has no function to perform, nor can it well be made to serve any useful purpose except to ward off the elements, and the usual construction, and each truss must carry the purlines, rafters, and planking, besides the roof covering and snow, for 20 or 30 feet in width. Aside from the buckling of the upper chord, it will take no more material to make two trusses of one-half the

strength or three trusses of one-third the strength than to make one large one, and while there will be more work, it will all be so much lighter and more readily handled, that it is questionable whether it is much more costly. It is even less costly when it is taken into account that

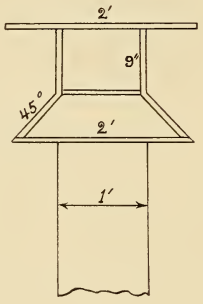


FIG. 3

the purlines and rafters are saved and so taken from the load on the trusses that they can be even lighter than one-half or one-third of the assumed heavy ones. The proposed plan assumes that the trusses are to be only 10 feet from center to center, or in some cases only 8 feet from center to center, and the roof planking made from 20-foot planking, or 16-foot planking in the other case, planed, matched, laid planed side down, the plank extending over three trusses and laid with break joints, so securing the upper chords that buckling is impossible.

Where wood is used for purlines and rafters, the protection against the spread of fire is greatly improved and pockets between purlines and rafters are avoided. Where this form of structure is used for a foundry, as is common also, the question of ventilation or monitor construction presents itself, and the way in which this is often treated does not look well. (See Fig. 1.) The engineer who makes a roof that way may claim that it is simple, that it stands, and what more do you want? It is just in these points that the engineer lacks the training of the architect, who would do the job as shown in Fig. 2, which brings rigid points of support under the weight of the monitor and the length of the compression member is shorter. It looks right, and, like other things mechanical, when it looks right, it is pretty safe to conclude that it is right.

About sixty years ago, more or less, one Emerson designed a form of stationary ventilator, that no matter in which direction the wind blew, air would be drawn up the vertical pipe. This is shown in Fig. 3. The same principle can be applied in foundry or other buildings where ventilation is required, as shown in Fig. 4.

In the sections of shops where there are no traveling cranes, but line shafts, counters, pipes, etc., the trusses 8 or 10 feet between centers offer special advantages. Line shafts not over $2\frac{1}{2}$ inches in size require supports and hangers as often as 8 feet, and 3-inch shafting as often as 10 feet, and there the frequent trusses supply a far better support than it is possible to get where trusses are 20 or 30 feet apart; and with the lower chords made as they should be, of two ell or channel irons, placed $\frac{5}{8}$ or $\frac{3}{4}$ inch apart, it is the most simple of all ways to bolt up hangers, counters or pipes. Bolts with suitable washers can be dropped down between the

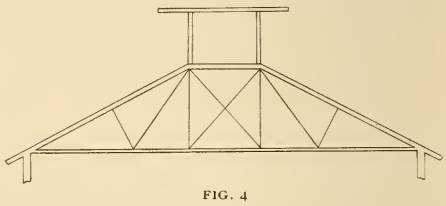


FIG. 4

two parts of the lower chord, and any kind of attachment can be made in the least time and without trouble.

The trusses being near together are many times more convenient for lifting machines or work with pulley blocks or tackle. The planking described serves for the foundation, whether shingles, gravel, tin, slate, or iron is used, and where even plank is dispensed with, to fortify against fire.

whatever is used in the place of planking will prevent the buckling of the upper chord.

Too much stress cannot be laid upon the advantage of the narrow spacing of the trusses, in doing away with the purlines and rafters, and the convenience in supporting the line shafts, counters, and overhead piping.

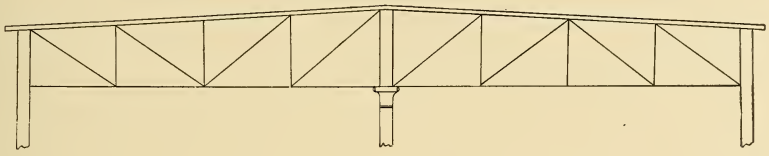


FIG. 5

It is well enough known by the designers of roofs that where the bracings are alternately long and short, the short ones are those that should be in compression and the long ones in tension.

This fact is often neglected, and it is not an uncommon thing to see designs like the one shown at the right-hand side of Fig. 5, and while that shown on the left side looks a good deal like it, it is enough different to be the difference between right and wrong. And, too, designers are so in the habit of using shapes for the various members as to ignore the advantage of flat bars for tension members.

The load on the long member is usually as much greater than the one on the short one as it is longer, and this calls for more rivets, and to meet this demand the wide flat bar furnishes the surface.

MOTOR CARS AS TRUNK RAILWAY FEEDERS

By George E. Walsh

THE service of regular lines of motor cars for feeding trunk railways in parts of the country where conditions do not warrant the construction of short steam or electric lines has been tried in various places, and its value is now pretty well appreciated. It has been particularly demonstrated along the coast lines where summer beaches attract a fair population in warm weather, but which are practically deserted in winter. A good many of these beaches are inaccessible except by omnibus or motor car, and their development depends almost entirely upon such auxiliary transportation facilities.

In America both the Long Island and the New York & New Haven roads have introduced motor cars as feeders for several of the isolated points along their route. In the winter season the motor-car service is entirely suspended, but in the warm months it proves popular and remunerative. The old omnibus lines will before long be entirely replaced by the motor cars where the traffic warrants the expense.

In Great Britain similar service has proved very attractive and profitable also. The first line was established there by the Great Western Company between Helston and the Lizard. The distance between the two points is 11 miles, and it is over a hilly section of the country. The

construction of a short steam or even trolley line would be rather expensive. The traffic is not heavy, but it is important in the summer season. Furthermore, it is believed that in time the coast along the Lizard will prove popular as a summer resort, and the railway made the experiment with the motor cars to see if the line could be made profitable for future use.

The line of motor cars established make the trip in an hour and a quarter, each car accommodating 32 passengers. The cars are of the Milne-Daimler gasoline type, developing 16 brake horse-power, and they connect with trains at certain hours of the day so regularly that passengers leaving the Lizard can depend upon an uninterrupted trip. Several villages are located along the route, and the passenger traffic is considered sufficient to keep several motor cars in constant operation through the day.

A more modern and more ambitious scheme of the Great Western Company is to establish a steam motor-car service through the Stroud Valley from Stonehouse to Chatford, a distance of 7 miles. The traffic through this valley is considerable, and by establishing the motor service the railroad company expects to develop a feeder that will steadily grow in importance. The cars used for this purpose are 56 feet long, a steam motor being carried in one end of the vehicle. Each car weighs 35 tons and accommodates 42 passengers. The motor is inclosed in a compartment where it is inconspicuous, and the funnel protrudes only slightly above the top of the car. The seats for the passengers run longitudinally on either side of a central aisle.

The construction of this new type of car as a feeder to the regular railway line has been brought about largely by the rivalry of the electric railways, which have diverted a good deal of the local traffic from the steam lines. Nearly every populous part of the country has been taken up by electric railways, and in order to hold its traffic the Great Western Company was prompted to establish short-route feeders of its own. By connecting all the small towns and villages along its route by petrol or larger steam motor cars it is hoped that the traffic will no longer be diverted from the steam to the trolley lines.

Another object which the Great Western Company has in view is the development of promising sections of the country. Many of these may be developed if properly supplied with traffic facilities. While it would be inexpedient to construct expensive steam lines through them, it is considered entirely practical to establish motor car lines, and later, if traffic growth warrants it, railway lines may be built. Thus the motor car routes are forerunners of steam railway lines. Moreover, electric railway companies are not apt to parallel a good motor car line, and the steam roads thus practically pre-empt the region for the time being.

A similar policy has been progressively pursued in the Western States of America. In the corn and wheat belt several motor car routes have been established as freight feeders for the trunk lines. The heavy motor cars put on the routes connect rich agricultural regions with the steam roads, and the cost of transporting grain to the stations is thus greatly cheapened. The whole problem depends upon whether the farmers show a willingness to turn their produce over to the motor car feeders in preference to carting it to the railway stations by their own teams. In the winter season the difficulties experienced by farmers in getting their produce to market is so great that they may welcome any change that promises improvement.

This brings the railways to the consideration of the trackless trolley, which has lately received so much attention in Germany and France. The trackless trolley supplies the missing link between the steam railway line

and the ordinary tramway. It runs on the common highways and requires no expensive roadbed or rails. It is an improvement upon the motor service, for the cost of operating the cars is less. The power is supplied by overhead trolley wires, but otherwise the service is totally different from either electric railways or steam railways.

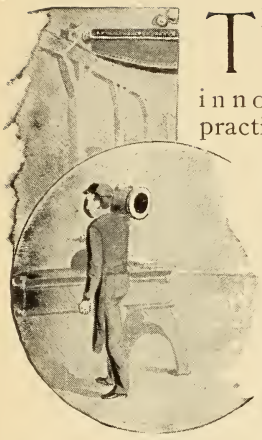
A trackless trolley line can be constructed at about one-third the cost of an ordinary electric railway, and the cars used for the line are operated at a little more expense, not counting the cost of interest and insurance on the equipment. As a railway feeder in sparsely settled regions, the trackless trolley thus promises changes for the better that several railways are now considering. Along the coast line a good many promising, but undeveloped, seaside places could thus be connected with the main steam line at comparatively little outlay of capital. In the winter season the service could be discontinued without causing any hardship or loss of earnings.

Ordinary firm dirt roads are suited to the service of the trackless trolley line. The broad-tired wheels of the cars improve the highway instead of injuring it, working the surface down solid within a few weeks so that lighter vehicles can pass over it without cutting deeply into it. Any prejudice existing against the trackless trolley on the score of destroying the highway should be dispelled after trial with one of the cars.

Altogether, the question of building feeders to cover short distances is one that railway companies must settle quickly in many places along their main lines, for the trolley lines are active in the field, and, as a rule, tend to divert traffic from the railways instead of serving as feeders, frequently paralleling the steam line, and thus competing directly in carrying freight and passengers.

HIGH-SPEED LATHES

By Joseph Horner



THE introduction of the high-speed cutting steels is the greatest innovation in workshop practice which the present generation has known. Though first introduced to the public notice so recently as 1900, lathe design is already being extensively changed in consequence. The collection of lathes which illustrates this article,—a small selection only,—would have been impossible four years ago, or even three; and manufacturers have in hand, and uncompleted, many variations in these types of lathes, designed with the special and sole object of utilizing the new steels to their utmost capacity.

Such a radical revolution as this in the mutual relations of tools and machines, is unparalleled in the history of workshop practice. Hitherto the machine has been the dominant factor; now the tool has become so. A movement that may be compared with this in a slight degree, occurred after the introduction of mild steel, for the manipulation and tooling of which the machines previously used for iron proved inadequate. Here the new material was the leading factor. The change affected rolls, shears, punches, lathes, planers and many other machines. But that movement was not comparable either in suddenness, or in the magnitude of its issues, with the one which we are now witnessing.

Mr. Barrow has banteringly termed the high-speed lathes "hydrocephalous,"—or lathes with "big heads and little bodies." But though the fast headstock is their most important and most prominent feature, it does not by any means comprise all the difference between the newer and the older types. The problem of the new steels is not met by taking a standard set of lathe patterns and making a new head for them. The whole design has to be remodelled, with improved belt and gear ratios, stiffer details throughout, and larger bearing surfaces.

The old problem of speeding up lathes was tried with the high-speed tools, with the result that they were pulled up by the tools. The workman's instinct has generally been opposed to much increase of speed,—using tools of water-hardened steel—and in the main it is correct. With the new brands of steel the attempt was seen to be hopeless from the commencement. Something can be accomplished thus, but nothing approaching that which the steels themselves will stand.

We have now arrived at that stage where turners have at command lathes by which the speeds of four years ago can be doubled, trebled, and quadrupled, and with proportionate increase in power. The old standard lathes absorbed remarkably little power; the new ones swallow up a very large amount. Cutting speeds had not increased much during the fifty years previous to 1900. The recent sudden change will involve, within a short space of time, the scrapping of large numbers of lathes, more in some works than others, but in all inevitably, to a greater or less extent, in the course of the next few years.

The high-speed lathes score most

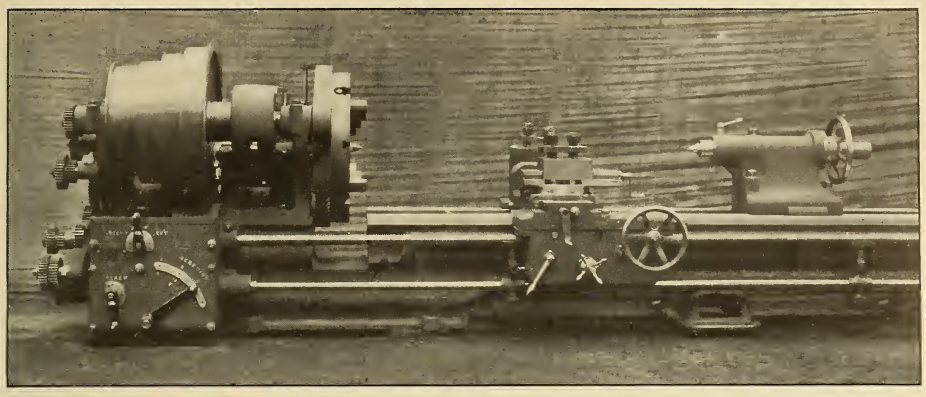


FIG. 1.—A LATHE MADE BY MESSRS. JOHN LANG & SONS, JOHNSTONE, NEAR GLASGOW

heavily in roughing down the massive forgings used in marine and heavy stationary engine work, pumps, etc., where allowances can never be cut finely. In shops where work in drop-forged, or pressed in dies, where castings are machine-moulded, or are of no great size, the economy that these lathes can effect is much less than in the former class of shop. And as the high-speed cutting steels are suitable for roughing chiefly, they will not show to very much advantage in any shop where finishing cuts occupy the chief proportion of the work of tooling. Nor again is their value quite so marked where castings chiefly are tooled, as where forgings of mild steel predominate, for it is on the low-carbon steels that the best results are obtained. But even with these limitations,—taking the average engineers' shops,—it appears that economies of from 30 per cent. to 35 per cent. may be easily secured by the use of these steels.

The value of high-speed lathes, though it seems paradoxical to say so, lies in a saving of power as well as of time. This is not the view which is popularly taken, in face of the obvious fact that several horse-power are absorbed by any high-speed lathe. But heavy cutting is much more economical of time than light cutting. And there is the fact that the number of hands and the number of lathes can be reduced in a shop equipped for high-speed work; or, alternatively a greater volume of work can be turned out with the same complement, where high-speed tools are substituted for the ordinary water-hardened ones. The power absorbed in the mere drive remains practically constant during periods of non-cutting, as well as when light or heavy cutting is being done.

A lathe designed to utilize the fullest advantages of the new steels must not only be stiff and strong, but possess a large range of speeds, combined with proportionate power. The embodiment of these conditions involves the abandonment of the small-stepped cones which have hitherto been usual. Regular geometrical gradations of all spindle-speeds, from the smallest step in the belt-drive to the largest, with the highest gear in, are very desirable if the fullest capabilities of the new tools are to be utilized. And as great increase in power involves wider belts, the drops between the cone steps must be small if the belts are to be shifted with facility. Though low-gear ratios must be included, yet high gears are also necessary, because the heaviest cutting has to be done with medium high belt speeds, which is the reverse of the conditions that exist in ordinary lathes. The fulfilment of these makes an extension of two-gear ratios desirable to lathes of even medium size, such as have been fitted

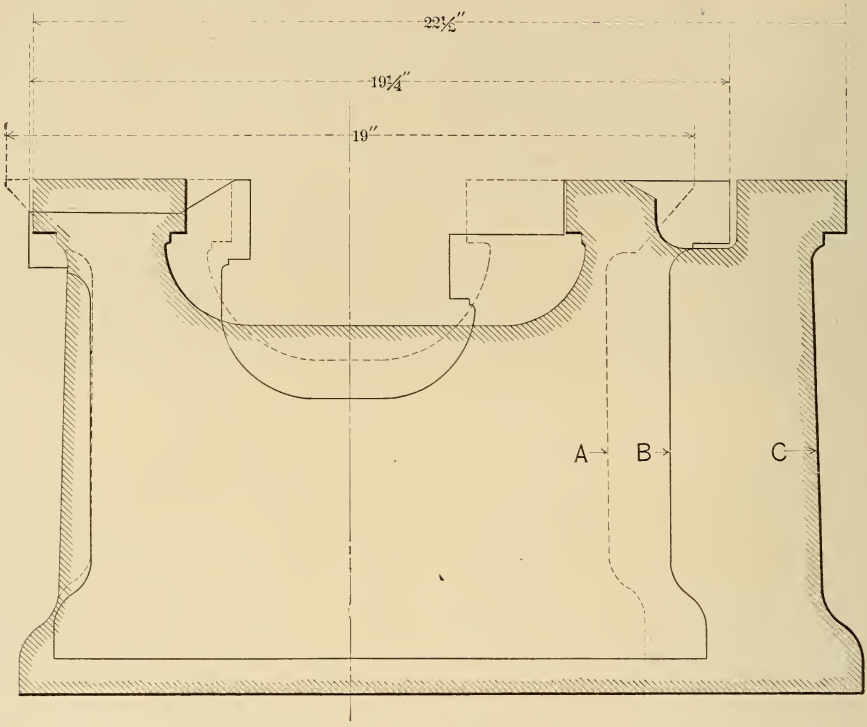


FIG. 2.—LATHE BEDS BY MESSRS. JOHN LANG & SONS, SUPERIMPOSED TO ILLUSTRATE THEIR EVOLUTION

with single back-gears hitherto. Then the demands made on the tool render general stiffening-up of the whole lathe necessary,—with longer slides, stronger gears, and stouter framings.

Another point is, that it becomes more than ever desirable to bring the pull of the lead screw and feed rod nearer to the bed, or to the center of the lathe carriage, than has been usually done. The stability of the carriage becomes of greater importance than formerly. The movable poppet has also to stand increased strains, for when a lathe is absorbing ten, twenty, or thirty horse-power, the parts of this, like the rest, have to be stiffer, larger, and stronger. And concurrently with these, improvements of recent years must not be neglected, notably the changing of feeds without stopping the lathe, a matter of greater impor-

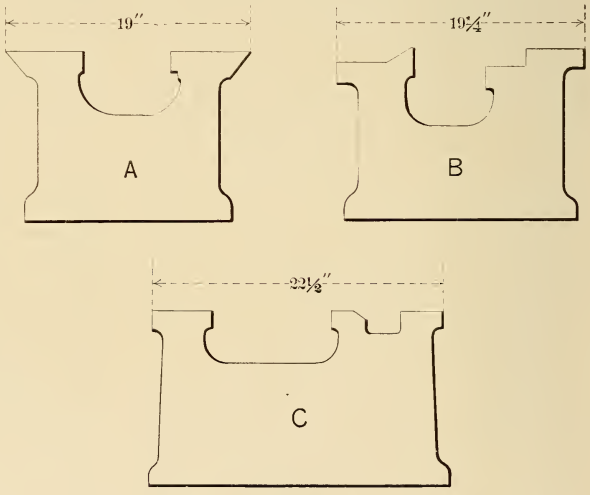


FIG. 3.—EVOLUTION OF LATHE BEDS AS MADE BY MESSRS. JOHN LANG & SONS. *A*, BEFORE 1900; *B*, 1900; *C*, 1903 TYPE

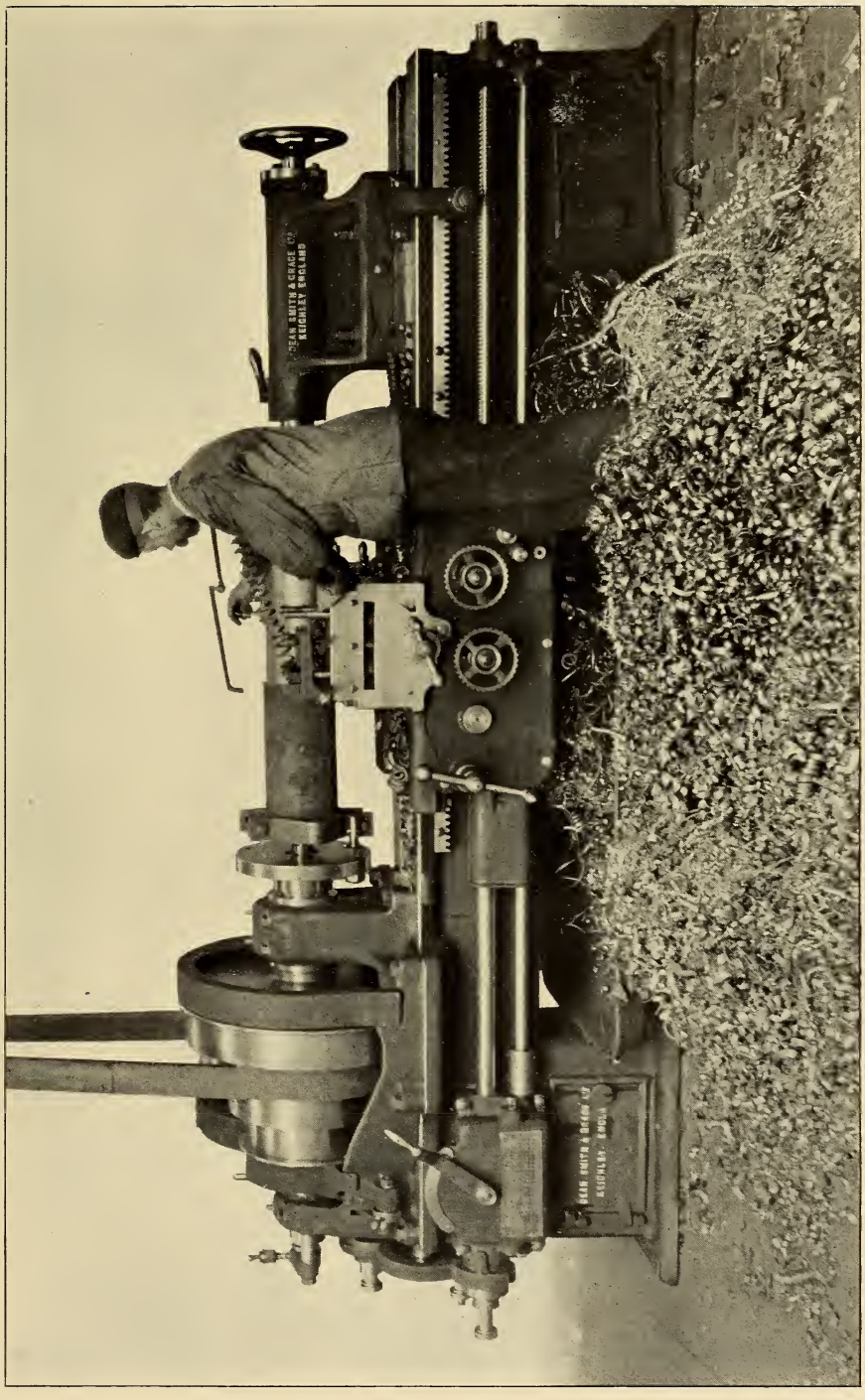


FIG. 4.—TWELVE-INCH LATHE CUTTING AT 90 FEET PER MINUTE. ONE OF AN ORDER OF FIFTY-FIVE FOR SHELL WORK FOR THE JAPANESE GOVERNMENT. BUILT BY MESSRS. DEAN, SMITH & GRACE, LTD., KEIGHLEY

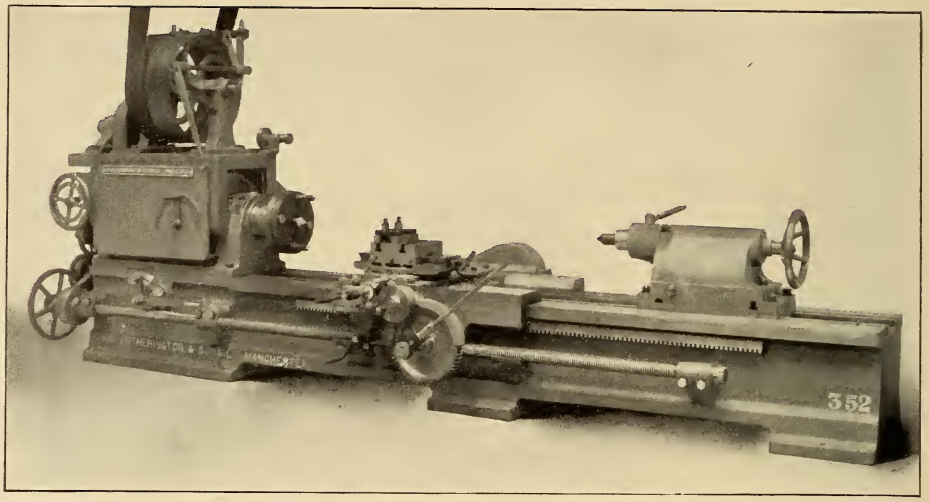


FIG 5.—LATHE WITH SPECIAL HEAD MADE BY MESSRS. JOHN HETHERINGTON & SONS, LTD., MANCHESTER. THE HEAD IS SHOWN MORE IN DETAIL IN FIG. 6

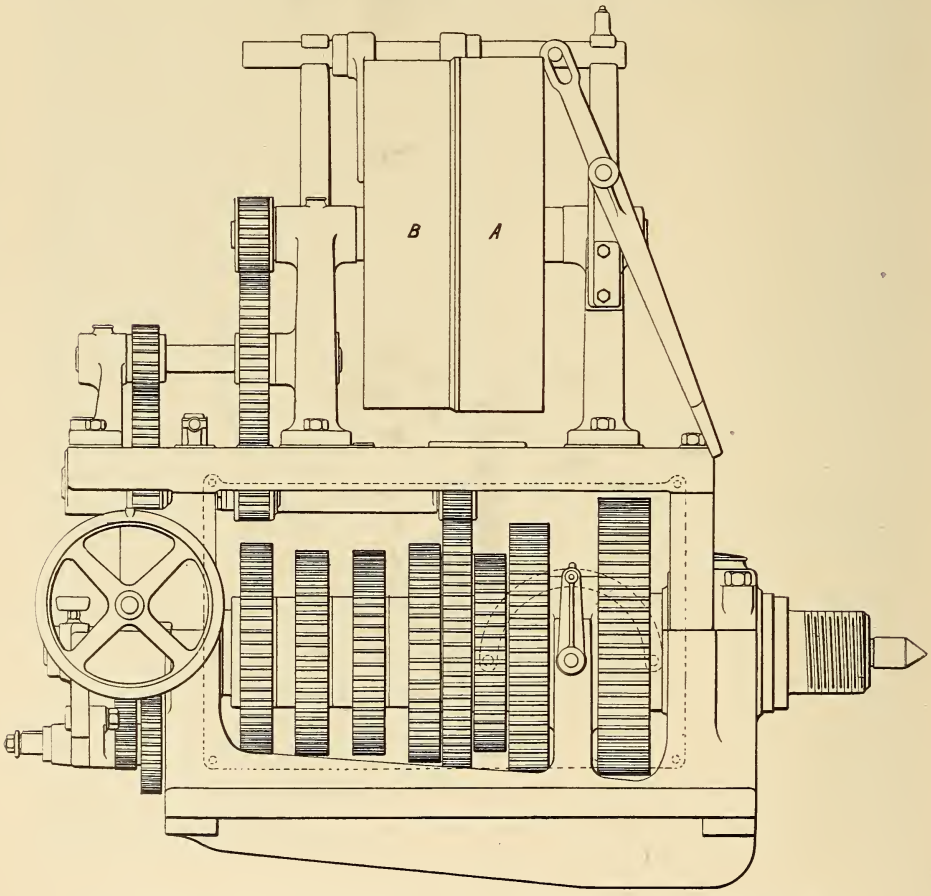


FIG 6.—ELEVATION OF FAST HEADSTOCK FOR THE HETHERINGTON LATHE SHOWN ABOVE

tance even than in the lathes operating with water-hardened tools. The question of a larger or smaller range of feeds is not nearly so important as the points just enumerated. Four to eight feeds cover all the requirements of ordinary work. The greatest variations in heavy and light cutting are made in the depth of cut, which in high-speed turning will range anywhere up to, and sometimes over, an inch.

British firms are adopting the heroic course of getting out new, though expensive, designs, instead of tinkering with the patterns of even two or three years since. The vastness of the revolution to which the new steels have given birth is fully grasped in Great Britain. And the new movement is being extended to include not only standard lathes, but those of more or less special types. A few examples of these will here be given.

The new design of high-speed lathes by John Lang & Sons, of Johnstone, near Glasgow, is an advance on their standard types of two or three years ago. The firm has for several years devoted its energies wholly to lathe construction, and has introduced several valuable improvements. Fig. 1, showing their new 16-inch center, high-speed lathe, interests one immediately by its unusual features, besides which there are several details of importance not apparent in the illustration.

Lang's patent bed. with the longitudinal guide and take-up strip, giving a guide about ten times greater than its width, is well known. It was illustrated and described in CASSIER'S MAGAZINE for September, 1901. Cross sections of the bed showing its evolution from the ordinary type to the present one are shown in Figs. 2 and 3 superimposed, by which an accurate comparison of proportions can be made; *A* is the design previous to 1900, *B* that in 1900, and *C* the design of 1903, the first named type being dotted, the second in full lines, and the latest in full lines, shaded.

Fig. 1 shows very large cones with moderate stepping down, ranging from 36 inches to 25½ inches. The gear ratios are 6 to 1 and 18 to 1 (treble gear), respectively. Roughing can be done at from 50 to 100 feet per minute surface speed, and a finishing speed of 16 to 30 then thrown in without altering the belt. The four standard feeds are 1-6, 1-12, 1-18 and 1-24 inch per revolution of spindle.

The placing the cone on a spindle separate from the main one, to which it is geared in a ratio of 1 to 6, adds greatly to the utility of the lathe for cuting worms and screws of coarse pitches. It effects readily what is often done in common lathes by driving the end of the screw, and driving backwards. The change wheels are arranged to gear direct from the cone shaft to the screw with comparatively little strain on the belt and change wheels. Being geared 6 to 1, equal wheels on cone shaft and screw will cut a pitch of 3 inches, using a lead screw of ½ inch pitch.

A detail which it has been found necessary to add to these large-coned lathes is a brake for bringing the lathe to rest quickly. The cones acting partly as a flywheel, would cause the revolutions to continue for some time after stopping the countershaft, so a brake has been introduced on the right-hand side of the cones, by which the spindle can be checked within one revolution.

The lead screw and feed rod are both in front, and neither can be revolved at one time, nor can sliding and surfacing feeds be in at one time. Lead screw and rod can be started and stopped or reversed while the lathe is running. Four different pitches of screws can be cut without stopping the lathe.

The firm of Dean, Smith & Grace, Ltd., of Keighley is also one of that limited number which specialize around lathes alone, in the manufacture of which they employ about 400 men. A hollow-spindle, high-speed lathe of 8½-inch centers by this firm,

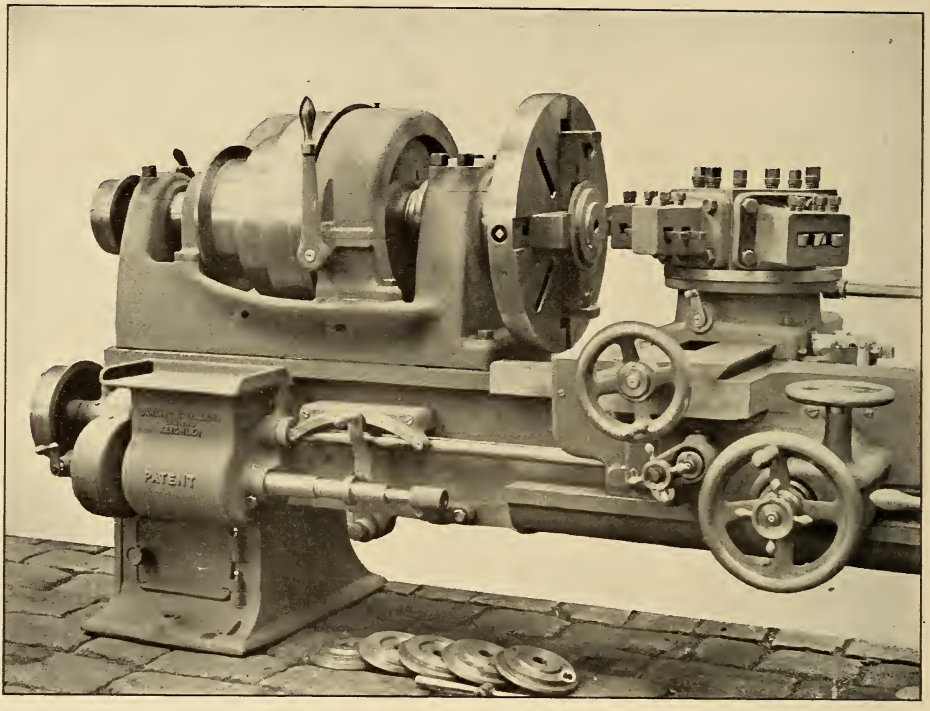


FIG. 7.—A CHUCKING LATHE, 13½-INCH CENTRE, WITH ABNORMAL HEAD. MADE BY MESSRS. DARLING & SELLERS, LTD., KEIGHLEY

has a 3⅝-inch hole through the spindle, and this involves a front neck 5½ inches in diameter by 7½ inches long,—an immense size for a lathe of these centers. The smallest cone step is 10 inches in diameter,—1½ inches greater than the height of centers, and the largest is 18 inches. Three cone steps, a double gear of 6 to 1, and a double countershaft, permit of 12 speeds; namely, 13, 18, 24, 33, 43, 60, 79, 110, 145, 200, 261 and 360 revolutions per minute. The change from single to double gears can be made without stopping the lathe, being effected through friction, operated by the handle in front. The feeds are through gears enclosed in the box beneath the headstock, changed by the handle in front and giving 32, 16 and 8 cuts per inch. The lathe includes provision for screw cutting, the change wheels being conveniently enclosed in cabinet feet.

The firm makes several other lathes varied in size and design for high-speed work. They have one of 12-inch and one of 16-inch centers, and a surfacing and boring lathe of 24-inch swing, fitted with a hexagon turret. The 8½-inch hollow-spindle lathe is furnished with a square turret in place of the ordinary compound rest, to carry four tools, for the entire finishing of, say, a motor shaft with roughing, finishing, cutting off, and threading tools. A centering attachment may also be fitted to the loose head; for centering a shaft immediately it is chucked.

The bed of the 12-inch center lathe measures 22 inches wide over the V's. The headstock spindle has a four-speed cone of large size, the steps ranging from 13 to 28 inches in diameter by 4¼ inches wide, and the gear is 8 to 1. The countershaft is double, and the spindle speeds are, with the gear out, 560, 332.2, 258.4,

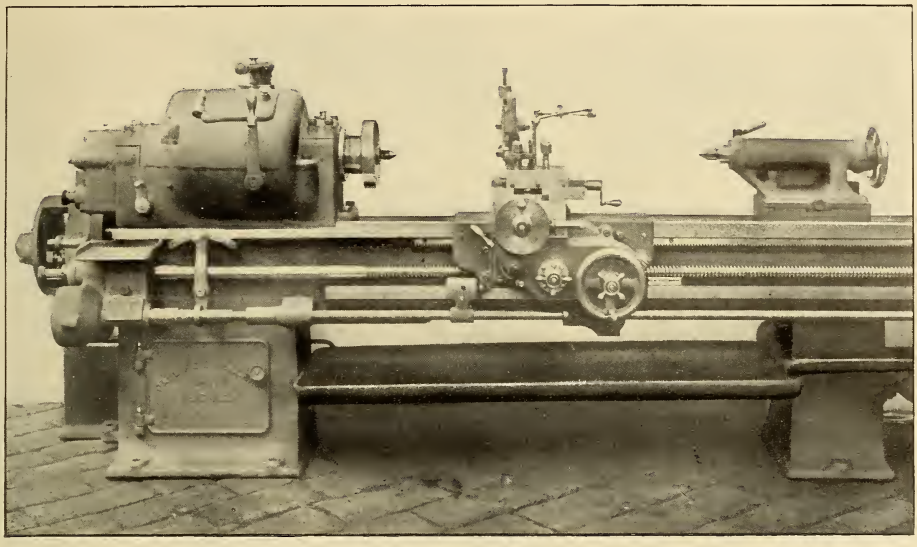


FIG. 8.—MOTOR-DRIVEN LATHE MADE BY MESSRS. DARLING & SELLERS, LTD., KEIGHLEY

203.4, 153.2, and 120.7, 93.8, 70, per minute; and with gear in 55.7, 41.5, 32.2, 25.8, 19.1 and 15.1, 11.64 and 6.84 revolutions per minute. This lathe is capable of reducing forgings by an inch in diameter, at $\frac{1}{8}$ inch traverse, at 50 feet per minute.

The 16-inch lathe has a five-speed cone pulley with steps $6\frac{1}{4}$ inches wide, and ranging from 12 to 34 inches in diameter. It is single geared, with a ratio of 13.8 to 1. Twenty speeds, from 566 revolutions to 5.04 per minute, are obtainable. The bed is 2 feet 6 inches wide and 18 inches deep, and troughs run under its entire length. These are mounted on castors. The 16-inch lathe will reduce forgings 2 inches in diameter at $\frac{1}{8}$-inch feed, at 50 feet per minute. It has removed 16 cwts. of metal per hour, with one tool cutting.

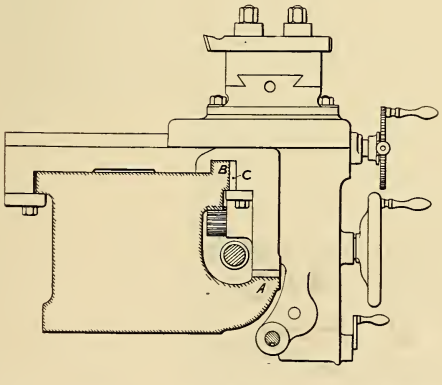


FIG. 9.—SECTION THROUGH DOUBLE TIER BED OF ABOVE LATHE

Many valuable points, more or less connected with high-speed work, may be noted. All these high-speed lathes, with the exception of the one of $8\frac{1}{2}$-inch centers, with $3\frac{5}{8}$-inch hole, and the 10-inch center with 5-inch hole through spindle, have a patent lubricating device for the fast headstock spindle. The spindle is bored up to the front end of the cone bearings, and it is drilled from the outside of the spindle to the hole in the center of spindle. Grooves are cut along the bearings whereby the cone is lubricated from the center hole that forms a well of oil fed by a sight-feed lubricator on the spindle end. The centers of the loose poppets are also lubricated by a solid lubricant. Pumps and piping are fitted to the lathes, so that the steels can be worked at higher speeds, and give better results than when run dry.

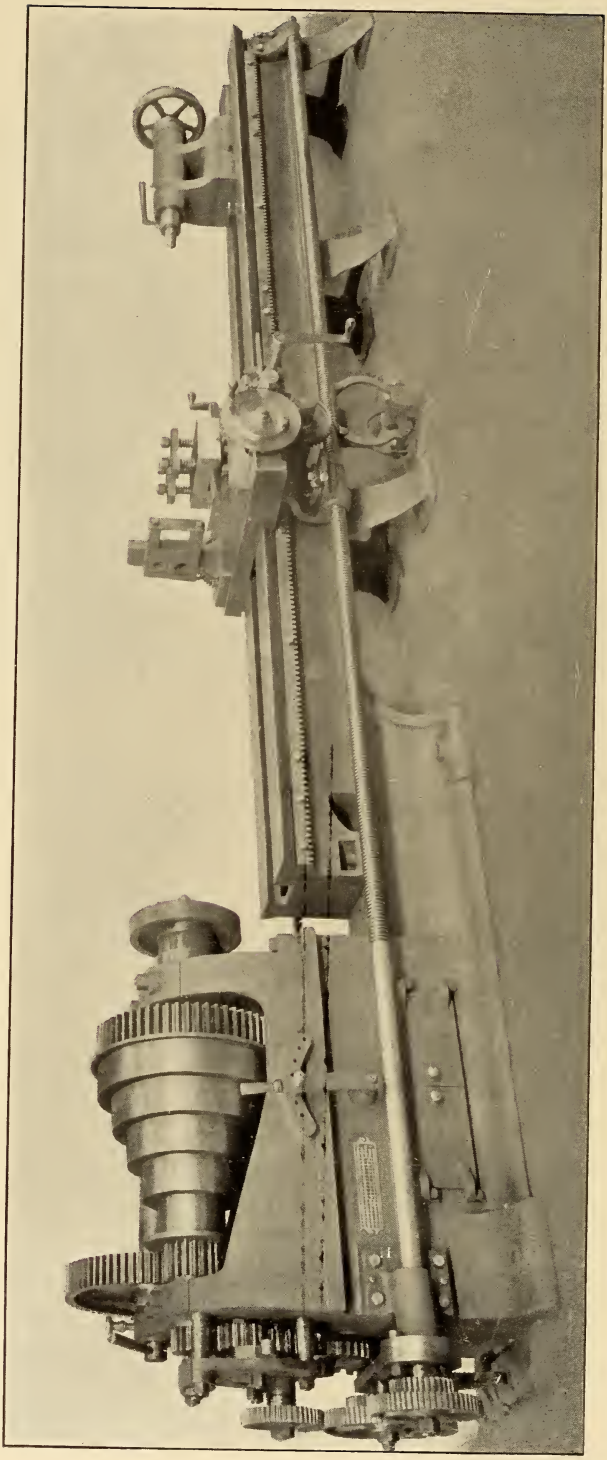


FIG. 11.—A 12-INCH CENTER LATHE FOR HEAVY CUTTING WITH HIGH-SPEED STEEL. MADE BY GEORGE ADDY, WAVERLEY WORKS, SHEFFIELD

A notable feature of the lathes by this firm is the abnormal width of the slides of the rests, by comparison with many previous British and American designs. Other points noticeable are hand wheels, indicating friction-operated feeds for sliding and surfacing, adjustable stops

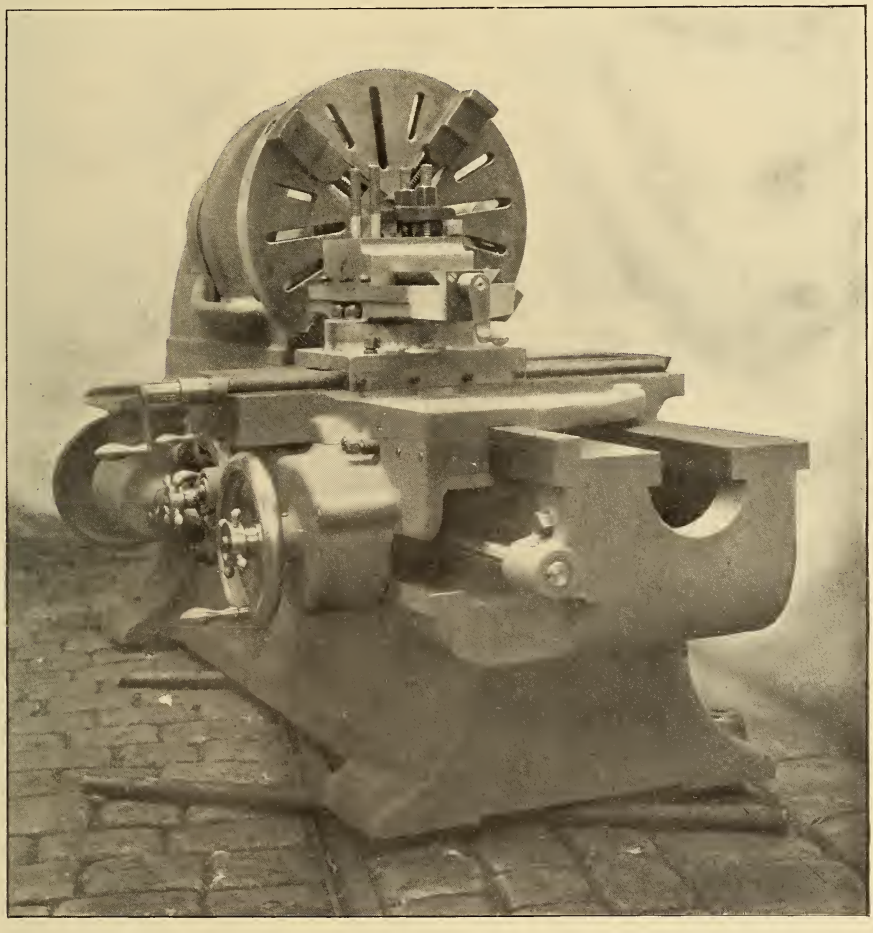


FIG 10.—END VIEW OF A FACING AND BORING LATHE, SHOWING SADDLE MOUNTING ON SPECIAL DOUBLE-TIER BED OF MESSRS. DARLING & SELLERS, LTD., REPRESENTED IN SECTION IN FIG. 9

for arresting the movement of the saddle at any point, the long cover over the lead screw, the large diameter of the lead screw and feed rod; the large size of the barrel and spindle of the movable poppet, and not least of all, the tray underneath for receiving the cuttings and the lubricant. A valuable feature of the $8\frac{1}{2}$-inch lathe with hollow spindle is an interlocking device which prevents risk of fracture of the parts. The saddle is fitted with a dropping worm, and by the interlocking device it is impossible for the nut to be dropped into the lead screw when the sliding friction is in. The action of putting in the nut drops the worm out of engagement, and when the nut is in it is impossible to fit the worm into gear.

John Hetherington & Sons, Ltd., of Manchester, are now making a set of special lathes sufficiently powerful

to be able to meet the utmost demands that can be made with regard to amount of material removed in a given time. They are in seven sizes, 8, 10, 12, 14, 16, 20 and 24-inch centers. To avoid the difficulty of moving the heavy belts which are necessary, Messrs. Hetherington have designed a headstock for these lathes with a constant-speed belt running on a driving pulley of fixed size, *A*, Fig. 6, carried by pedestal brackets mounted above the lathe spindle. A loose pulley *B*, of slightly smaller diameter than *A*, relieves the stress on the belt when the lathe is not in operation. The headstocks are so designed that the belt pulleys can be readily replaced at any time by an electric motor carried by, and self-contained with, the headstock.

The cone pulleys ordinarily used are replaced in these lathes by a set of gears of four ratios, any pair of which can be put in use by means of a hand wheel placed on the front of the headstock, the hand wheel being indexed to show the pair of gears engaged in driving, similar to the usual belt position. The headstocks are also provided with the firm's usual three-ratio driving gears of 4, 8, and 16 to 1 purchase. By means of these gears approximately any diameters equal to the height of centers of each size lathe downwards can be operated on at a cutting speed of 100 feet per minute, or at any higher or lower speed as may be deemed essential for the class of work to be operated upon. This arrangement of gears provides 12 changes of speed arranged in geometrical progression, any speed being almost instantly obtained by means of the hand wheel and a lever placed at the front end of the head.

In order to render these lathes more generally useful, the makers provide in addition a set of reduction gears, by the aid of which the gears for high-speed cutting—4, 8, and 16 to 1—can be instantly increased to ratios of 32, 64, and 128 to 1, giving in all a total number of 24 changes of speed to the spindle,—12 changes for high-speed cutting, and 12 for ordinary or finishing speeds ranging downwards from 100 feet per minute to 12½ feet per minute, all the speeds being in geometrical progression.

The driving pulleys of this series are 18, 22, 26, 30, 34 and 42 inches in diameter, respectively, arranged to take belts of 4, 5, 6, 7, 8, and 10 inches wide. The feeds for sliding and surfacing are positive and arranged to give 4 changes,—1-32,

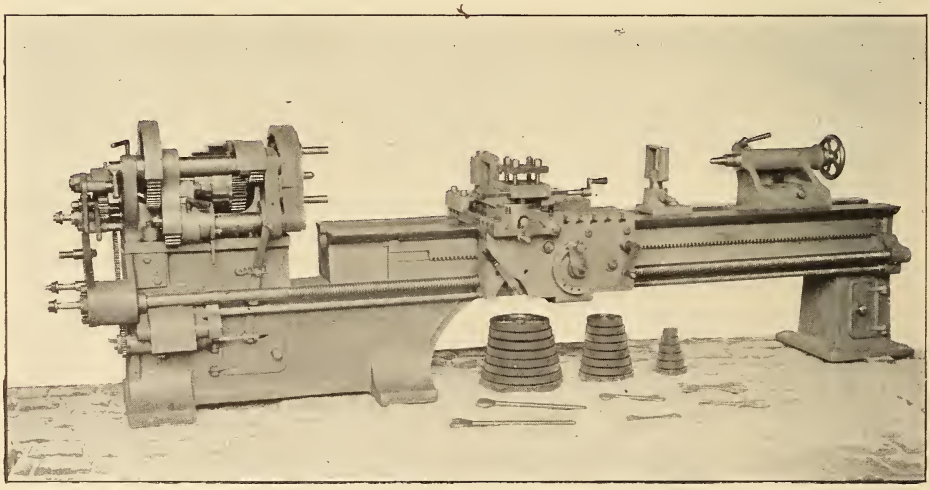


FIG. 12.—HIGH-SPEED LATHE MADE BY MESSRS. G. WILKINSON & SONS, KEIGHLEY

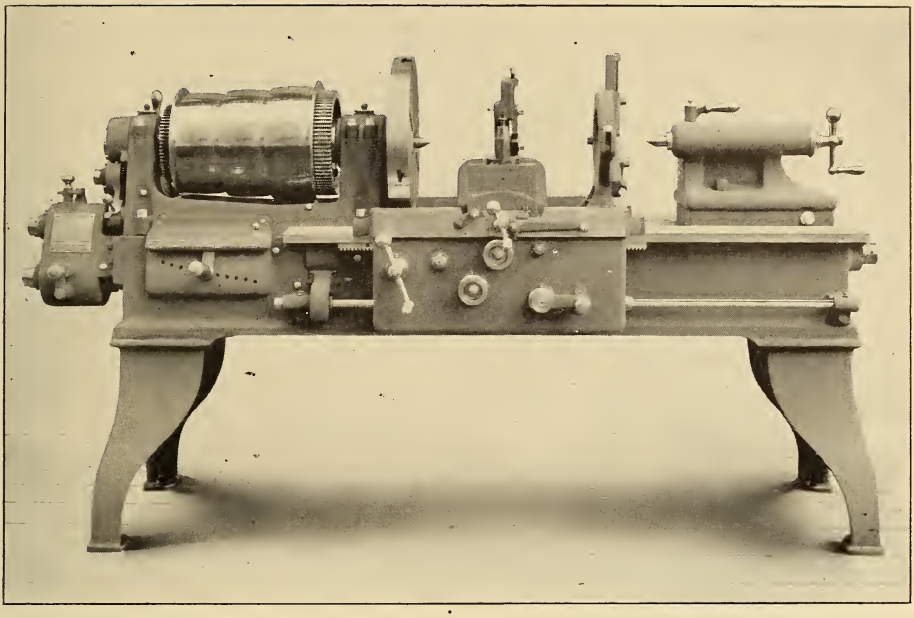


FIG 13.—SPECIAL SHAFT AND SPINDLE-TURNING LATHE MADE BY THE AMERICAN TOOL WORKS CO., CINCINNATI, OHIO, U. S. A.

1-16, $\frac{1}{8}$, and $\frac{1}{4}$ inch per revolution of spindle,—by an instantaneous change effected by a lever at the front.

Messrs. Hetherington claim that these lathes are the most powerful for their size at present, and they suggest the following method of ascertaining the comparative belt and gear efforts of different lathes:—

The belt effort equals the diameter of the pulley, or the largest cone in the fast headstock × width × gear ratio. Thus, for example, taking the 14-inch Hetherington special lathe,—

Diameter of pulley or large cone in fast head 30 inches by width 7 inches by gear ratio 16 to 1,—

$$30 \times 7 \times 16 = 3360 \text{ units.}$$

These units are exclusive of the reduction gears which, if taken into account, would make a total of 26,880 units. If lathes by various manufacturers are compared in this way, some very striking differences will be observed in the belt efforts, or units; and the value of the cones, both large and wide, and of high gear ratios becomes at once apparent.

We have seen that the ideal high-speed lathe must include powerful cuts as well as medium high speeds. All the lathes now reviewed combine provisions for each great class of work,—great power for cuts up to moderate speeds, and high speeds with belt power alone, or with single gear. We may anticipate that the employment of the high-speed tool steels will eventually oust the ordinary one-ratio double gear from lathes of medium size, in favour of the two-ratio gears of the larger ones to which it is commonly fitted. It is difficult, with a single set of double gear, to combine satisfactory cone dimensions to give the wide range of speeds and powers demanded by the new tools. To this particular aspect of the problem the following remarks are applicable.

With a single ratio of gears, what happens in an ordinary lathe is, that speeds are fairly graded when running with belt alone, or with gears in, but there is a big gap between the two. This has been generally tolerated, but its disadvantages are glaring under the new conditions. If the high

speeds of which the tools are capable are to be secured by one set of back gears, the ratio of these gears must be small. But then the power is reduced thus, and the maximum area of cut is sacrificed. On the other hand, if the gear ratio is made high, then big drops in the cone steps are necessary, and steps of small diameter, with hard belt shifting, both of which are most undesirable. A high efficiency on the smallest cone step and ease of movement of the belts are the most desirable, and these can only be properly secured with large steps and two-ratio speeds. A two-speed countershaft is further desirable if a very extensive range of speeds is to be obtained. It is on these lines that firms are now working.

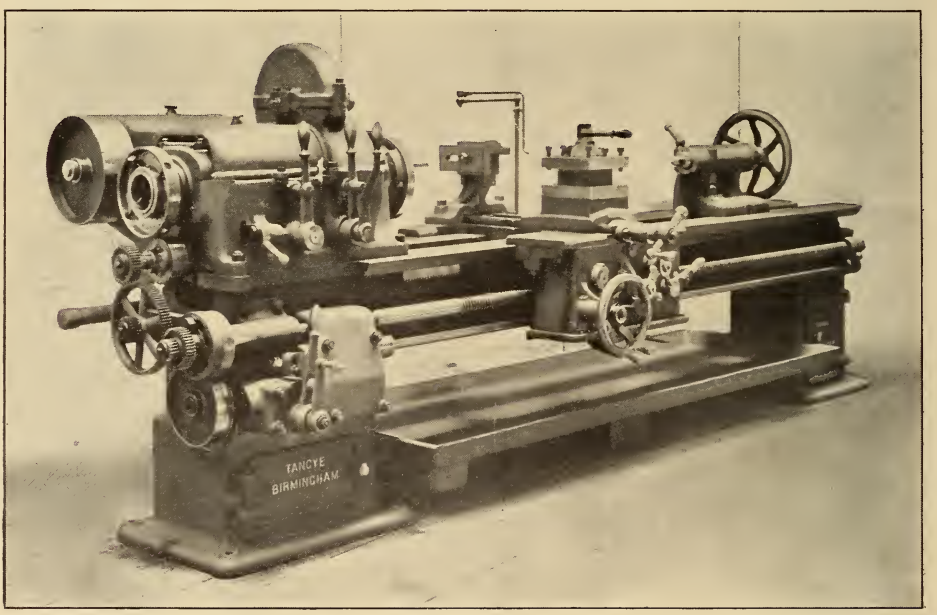


FIG 14.—CAPSTAN LATHE MADE BY THE TANGYE TOOL & ELECTRIC CO. LTD., BIRMINGHAM

In the high-speed lathes by Messrs. Darling & Sellers, Ltd., of Keighley, a two-ratio driving gear is used, and the driving speeds proceed in geometrical progression from belt to low ratio. The efficiency of these lathes is enhanced by the large size of the bottom step of the cone. It seems certain that the employment of high-speed steels is best provided for by some such modification of the ordinary one-ratio gear on lathes of medium size, as well as on the larger ones. In the series of high-speed lathes by Darling & Sellers, Ltd., the smallest cone steps in lathes of 9, 10½, 12½, and 16½-inch centers, measure respectively 11¾, 14, 16, and 20½ inches in diameter, and without sacrificing geometrical progression. Moreover, the relation between the countershaft speeds and the high and low-gear ratios is such that either of these changes may be utilized for slowing down at once from a fast roughing surface speed to a slow finishing surface speed without moving the belt on the cone. No excuse exists, therefore, for running at the same speed for both roughing and finishing cuts because of the difficulty of shifting the broad belts on the cones.

An important matter in tests, but one which is not generally mentioned, is the ratio between belt and cutting speed; the inter-relation be-

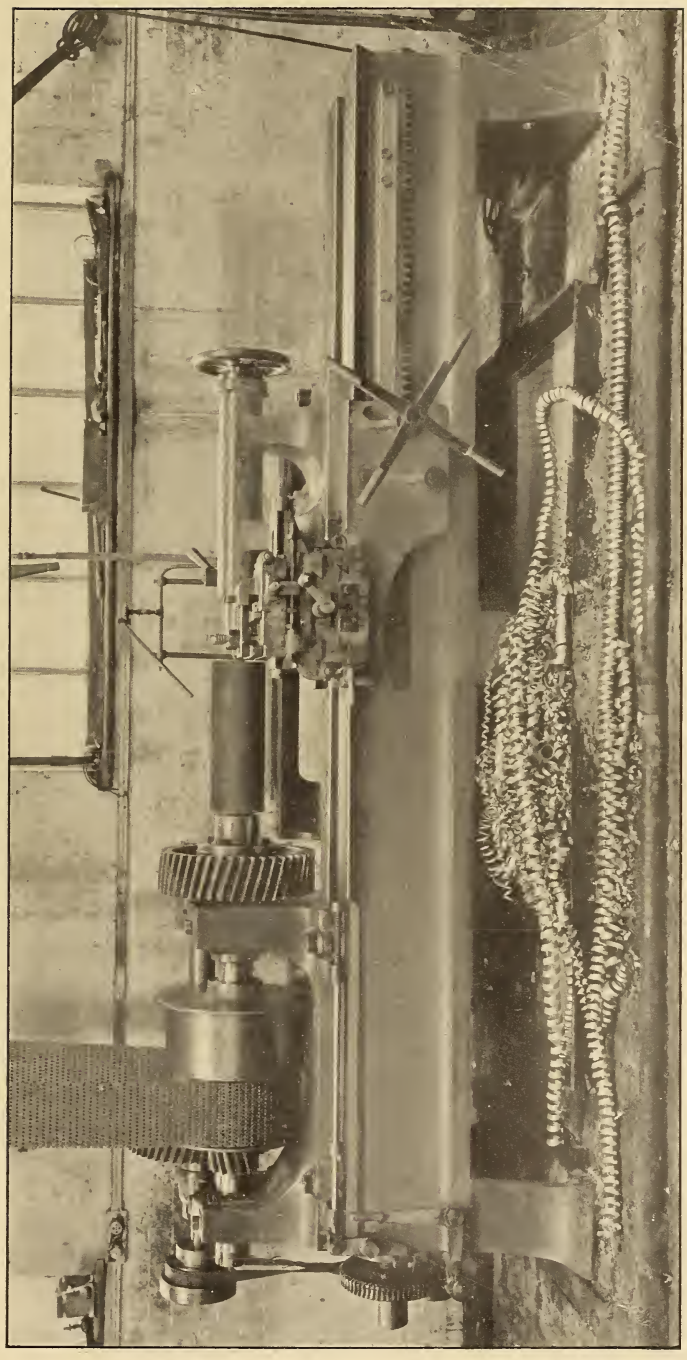


FIG. 15.—A 12-INCH CENTER LATHE FOR HIGH-SPEED WORK MADE BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., MANCHESTER. DRIVEN BY A LINK BELT

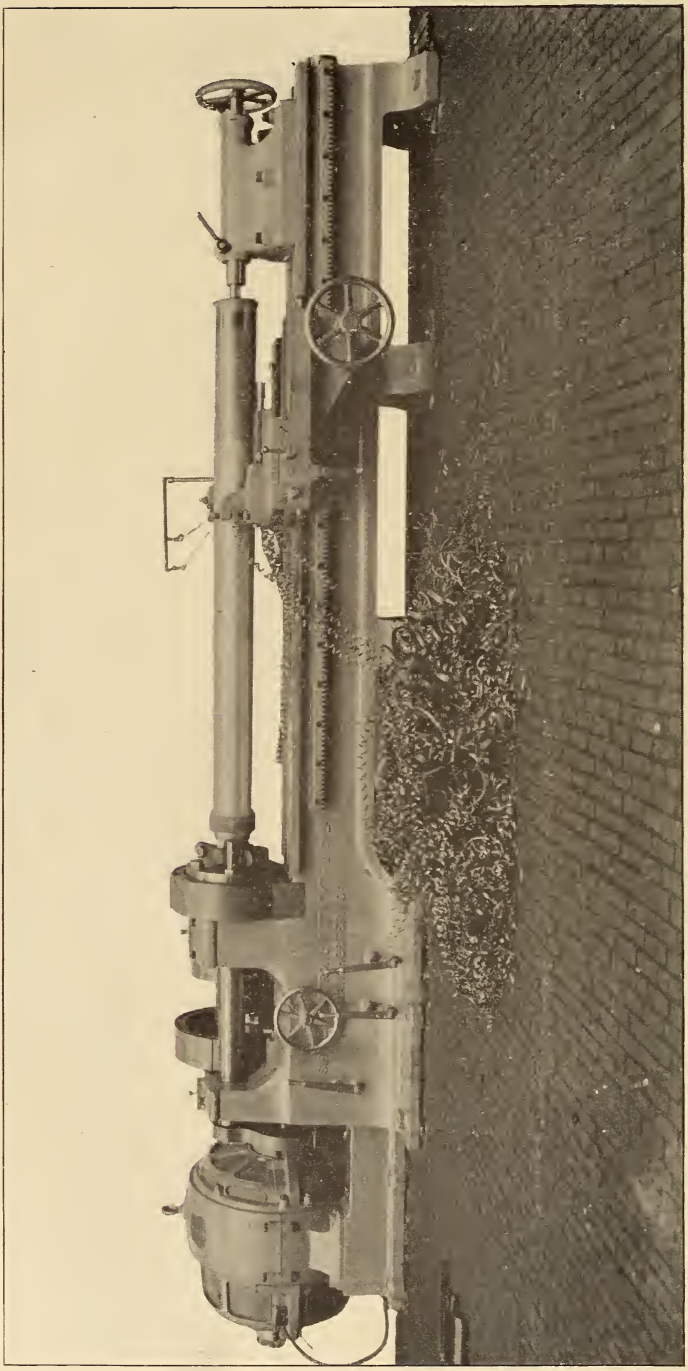


FIG. 16.—HIGH-SPEED LATHE SHOWN AT THE LIEGE EXPOSITION BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., MANCHESTER, DRIVEN BY A VARIABLE SPEED ELECTRIC MOTOR GIVING FACE PLATE SPEEDS FROM 25 TO 320 REVOLUTIONS PER MINUTE, CAPABLE OF TURNING IRON AND STEEL AT SPEEDS UP TO 340 FEET PER MINUTE

tween the two being so close that unless both are clearly stated it is quite possible to show a light lathe removing almost as many pounds of metal per hour as a heavy one. Thus, although in the Darling & Sellers 16½-inch center lathe, 750 pounds of mild steel per hour were removed, at 60 feet per minute, over 400 pounds per hour have been removed on their 10-inch size with the low-ratio gear only, before it was fitted with the abnormal headstock, thus showing that the above record does not approach the maximum for the heavier lathe.

Four lathes are built in this series, of centers 9, 10½, 12½, and 16½ inches. Taking one of these,—the 12½-inch,—there are 18 spindle speeds obtainable with the two-speed countershaft. The fast gear ratio is 5.7 to 1; the slow, 12.8 to 1. Direct motor-drive is also applied.

The feed-gear box is furnished with four pairs of wheels, set in reverse of the usual order, either pair being thrown into action by means of a sliding spring-key entering the grooves in the driving wheels. Four feeds are provided, 1-32, 1-16, ⅛, and ¼-inch per revolution. The feed change is operated instantly without stopping the lathe. The feeds at the saddle are thrown in by friction cones of ample surface to carry the heaviest cuts. The feed reverse is placed on the saddle itself,—a convenient provision, especially on long lathes.

An important variant in the largest lathes is the placing of the back gears in an independent headstock in front of the cones. This permits the spindle to be carried in three bearings, and as no webs are required to support the front bearing, there is no restriction to the belt angle. This radical departure from common practice appears to be of much promise.

The double-tier bed introduced by this firm on all their high-speed lathes combines a narrow front guiding strip with an auxiliary bed or ledge set at a lower level upon which the front overhang of the saddle is supported. In this way also the effective width of the bed is increased by the amount of the distance to which the ledge stands out beyond the bed. The lead screw and rack lie within this auxiliary bed close to the guiding strip and nearer to the tool than is possible with any form of wide upper bed. A section through this and the saddle is given in Fig. 9, in which the auxiliary, or lower-tier, bed is seen at *A*, with Lang's narrow front guiding strip and wedge take-up strip at *B* and *C*, respectively. The take-up strips for the square guiding edges are shown, and the snug location of the lead screw will be noticed.

George Addy, of Sheffield, has a high-speed lathe of 12-inch centers, shown in Fig. 11, which is built on the standard British model, but stiffened up and made more powerful. Thus, the front neck of the spindle is 6 inches in diameter by 8 inches long. The cone steps are 4⅛ inches wide. The back gears are of 3 pitch and 2½ pitch, respectively. The feeds are controlled by the handle in front of the lathe. Using Mr. Addy's own "Z" steel, chips ½ an inch deep have been taken off a steel shaft, with a feed of 10 to the inch, at 50 feet per minute. A speed of 80 feet has also been attained.

Messrs. G. Wilkinson & Sons, of Keighley, make a lathe of 9-inch centers for high-speed work, with single, double, and treble back gears, the highest power obtainable being 27 to 1. The general features of the lathe, shown in Fig. 12, may be classed as modern. The feed rod is in front, and it is positively driven by a pitch chain. Three feeds are obtainable without stopping the lathe. All the self-acting motions are controlled from the saddle.

This is an example of a lathe suitable either for high-speed cutting or for tools of ordinary steel, and is therefore adapted to the requirements of the general shop, which is still the principal field which machine tool makers have to consider. We will

now look at a lathe that is designed on extreme lines.

The experiments in America of H. M. Norris, of Cincinnati, on "Novo" steel, demonstrated the need for the design of speed cones and gears affording small increases in successive spindle speeds. These experiments were made primarily with the object of ascertaining the best practice for turning shafting laying between 1 inch and 4 inches diameter. In a lathe dealing only with this range of diameters, Mr. Norris has evolved a back gear ratio of 2 to 1; a three-stepped cone having diameters of 11 17-32, 12 11-32, and 13 inches, and a two-speed countershaft. He thus obtains 12 speeds ranging between 668 and 167 revolutions per minute, neither of which is less than 10 per cent. below a standard cutting speed of 175 feet per minute, which his experiments on Novo steel indicated as the best for the shaft turning in question. This, of course, is a case of very specialized work suitable for shafting, but the principle embodied is capable of extension to lathes of larger range.

Mr. Norris' experiments were carried out only on what we should in Great Britain class as light cuts and feeds. The heaviest were only $\frac{1}{8}$ inch in depth and 3-64 inch in traverse, which are not at all out of the way for ordinary steel tools to tackle. But the general deductions drawn are, that for work comprised within a limited range, the cone speeds,—four or five in standard lathes,—are more numerous than necessary, and involve smaller steps than are desirable. These and the high back gears give extremes of speeds that are seldom wanted, and also irregular gradations of speeds, some of which, too, are not required.

There is no reason why these anomalies should be perpetuated in newly designed high-speed lathes. In fact, it might be well to specialize these lathes further by the embodiment in them of a few speeds adapted for a moderate range of diameters only. In this way the highest possible efficiency might be secured, with no material disadvantages. This argument, as previously remarked, though that of the specialist, is germane to the subject of the relations of cones and gears which shall combine medium high speeds with high power, and easy and regular gradations of spindle speed.

The ideas of Mr. Norris are embodied in a high-speed lathe brought out some time ago by the American Tool Works Company, of Cincinnati, U. S. A. Fig. 13 shows one of 18-inch swing,—larger sizes being 20 inches and 24 inches. The lathe is primarily designed for shaft and spindle turning, in sizes ranging between 1 inch and 4 inches diameter. The steps and gears are graded so that cutting speeds can be obtained of from 150 to 200 feet on shafts of the sizes named above. On the 18-inch lathe (9-inch centers) the largest cone diameter is $12\frac{3}{4}$ inches, the width being $4\frac{7}{8}$ inches. Twelve changes of speed are available, and 44 feeds, without stopping the lathe. A cutting speed of 425 feet per minute has been obtained simply with the object of testing the strength of the lathe. This design is interesting as an example of a specialized type adapted to the production of a class of work limited in size.

The Tangye Tool & Electric Company, Ltd., of Birmingham, have gone to work in a different manner at the speed-cone difficulty, for they have a design of 16-inch center lathe in which stepped cones are entirely abandoned in favour of a single driving pulley of 21 inches diameter (see Fig. 14), to take a belt 8 inches wide, the rest of the head comprising gearing. The small steps of ordinary cones are not only thus eliminated, but the trouble of belt shifting is avoided, changes being easily effected in the back gears. Further, the width of belt insures ample power without running at excessive speed. In no case does the pulley rate exceed 500 revolutions per minute.

Since variations in speed at the headstock are obtained only by the back gears, of which there are four changes, a large range has to be obtained elsewhere. To accomplish this, the lathe is designed so that it may be driven either through a countershaft or from a motor. If through the first, the variable counter supplied has four changes of speed, which, with those on the back gears, render minute variations of about 1.3 to 1 in spindle speed available. If a motor is used, the one designed will run at any speed between 300 and 700 revolutions per minute without sparking at the commutator. To insure this result, the strength of the magnets is varied with a small shunt rheostat, and the speed therefore does not vary with the load. The motor is of 40 B. H. P., and the lathe belt, when at its slowest speed, absorbs from 25 to 30 B. H. P.,—a striking illustration of the power required for the new duties imposed by high-speed tool steels.

The live spindle of the 16-inch lathe is of hard forged steel; it measures 8 inches in diameter in the front bearing by $11\frac{3}{4}$ inches long, and its hind one is $5\frac{1}{4}$ inches in diameter by $7\frac{1}{4}$ inches long. The movable poppet has a spindle $5\frac{1}{4}$ inches in diameter. The lathe bed is 30 inches in width over the slides, by 18 inches deep. The feed shaft is in front, below the lead screw; and gears,—belt-operated,—provide six changes of feed of 4, $6\frac{1}{2}$, 10, 16, 26, and 40 to the inch, changeable by levers without stopping the lathe. The lead screw is $3\frac{1}{4}$ inches in diameter.

The saddle is of a special design to withstand the severe stresses of cutting. Thus, the feed gears are inclosed in a double apron, and the rack pinion has its axis vertical, throwing the rack more nearly under the cutting tool and affording a bearing to the pinion spindle above and below. These are the features of the lathe which are especially embodied for heavy cutting, with which alone we are concerned. Before it was bolted down, a steel shaft was reduced in it at a speed of 84 feet per minute, with a cut $\frac{5}{8}$ inch deep and a traverse of $6\frac{1}{2}$ to the inch.

Messrs. Sir W. G. Armstrong,

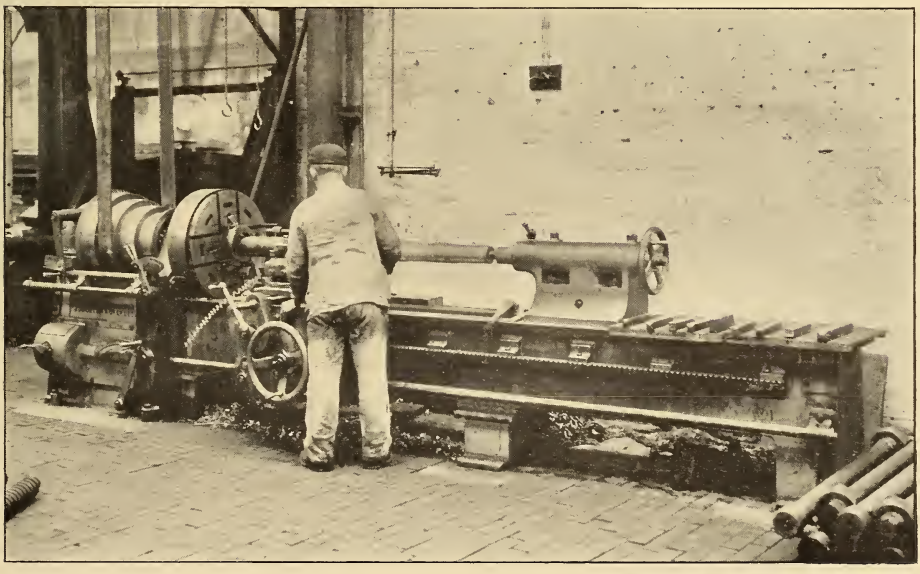


FIG. 17.—TURNING LOCOMOTIVE AXLES IN A 12-INCH LATHE MADE BY MESSRS. J. BUCKTON & CO., LTD., LEEDS, IN THE SHOPS OF MESSRS. CAMMELL, LAIRD & CO., LTD., SHEFFIELD

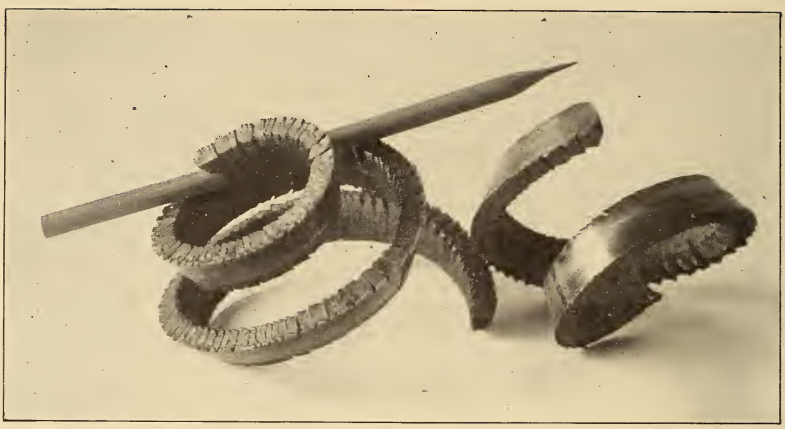


FIG. 18.—MILD STEEL SHAVINGS REMOVED AT A CUTTING SPEED OF 60 FEET PER MINUTE; DEPTH OF CUT, $\frac{3}{8}$ INCH. AT THE WORKS OF MESSRS. CAMMELL, LAIRD & CO., LTD. 30 H. P. ABSORBED

FIG. 19.—MILD STEEL CHIPS REMOVED WITH A CAMMELL-LAIRD STEEL TOOL AT A CUTTING SPEED OF 50 FEET PER MINUTE; DEPTH OF CUT, $\frac{1}{2}$ INCH; TRAVERSE, $\frac{1}{4}$ INCH; 34 H. P. ABSORBED

Whitworth & Co., Ltd., have done a great deal of experimenting with high-speed steels at their Openshaw Works, at Manchester. At the present time they have on hand several types of lathes for this class of duty. A 12-inch center lathe has been fitted with a two-speeded cone pulley, driven by a link belt (Fig. 15), and having helical back gear. On this lathe work has been turned at a cutting speed of 150 feet per minute, the cut being $\frac{3}{4}$ inch deep and the feed 24 to the inch. If required, a speed of 400 feet per minute can be obtained for fine cutting. Or at a lower speed heavier cuts can be taken. A 12-inch lathe, motor-driven, is shown in Fig. 16.

In the light of present experience, it seems probable that one result of high-speed cutting will be to favour the applications of the motor-drive to lathes. Whether the very wide

FIG. 20.—TURNINGS FROM A STEEL BAR, MADE AT A CUTTING SPEED OF 52 FEET PER MINUTE. DEPTH OF CUT, 1 1-32 INCH; FEED, $\frac{1}{8}$ INCH PER REVOLUTION; DURATION OF CUT, 30 MINUTES; WEIGHT OF METAL REMOVED IN THAT TIME, 660 POUNDS. FIRTH'S "SPEEDICUT" TOOL STEEL, MADE BY MESSRS. THOMAS FIRTH & SONS, LTD., SHEFFIELD

belts necessary for conveying the power to the new lathes are retained or not, the motor may prove the best operating mechanism. It may happen that it will displace the belt altogether and effect the drive through gears, between which and the variable speeds obtainable electrically the problem of small increments of speed ranges may be solved.

A point in favour of this application is that speed changes which are desirable can be effected thus without that expenditure of muscular energy which is involved in frequent changing of belts, and also without delay. The workman will thus have no plea to urge against making repeated changes in speeds to suit work of different diameters, and for different depths of cut for finer and coarser feeds, and to accommodate different materials.

Further, the new steels are likely to settle the question of belt vs. gear feeds in favour of the latter. The powerful pull on the carriage which is necessary to take the big area of cut that the driving power and the tools will stand can be met only by gears or by broad belts. The objection to feed belts transmitting great power is their shortness of drive. The slight advantage which they are supposed to possess is that they will slip under excessive strains, while gear teeth might break. This, however, need not weigh heavily on design, because feed gears, like the rest of the details of the lathe, can be strengthened to any extent. And there is always the alternative of fitting a safety device, such as a shearing pin. The present tendency is in favour of gears, and it is a reflex of the ideas of many lathe men.

We have seen that the problems of the high-speed lathe are in several

respects the reverse of those which exist in the ordinary type, using common tool steels. Closely related to the questions of speed and of strength, there is another,—that between roughing and finishing cuts. This arises from the fact that the high-speed tools are not capable of producing a fine finish, but they are mainly "sloggers." The result is that the ordinary practice for which all lathes are designed, to rough slowly and finish quickly, has to be reversed. The roughing has to be done at a high speed, or medium high speed, and the finishing, if required fine, at a slower speed, with the same or with water-hardened tools.

Perhaps in shops doing repeat work this problem will be solved by keeping one set of high-speed lathes for roughing only, transferring the work for the finish to ordinary lathes. Such a division of tasks would harmonize with modern ideas. Another result, the writer thinks, will be a great development of precision grinding. A vastly larger volume of work is ground now than formerly, but we may anticipate that still more will go to the grinder in preference to troubling about finish cuts in the lathe. This would be better from the point of view of accuracy, and would undoubtedly prove more economical under a good management. But if finishing as well as roughing are to be done on one lathe, and both in an efficient, and not a makeshift, way, then the back gears and cone pulley and countershafts must be designed to give greater power on the fast speeds than on the slow. Since the back gears have to be speeded up, they must be cut carefully to avoid noise, or, better still, helical cut gears will be used, as in the Whitworth lathe and many Continental ones. The smallest step of the cone pulley must be considerably larger than those in common lathes, and the countershaft should have an extra-quick set of roughing pulleys.

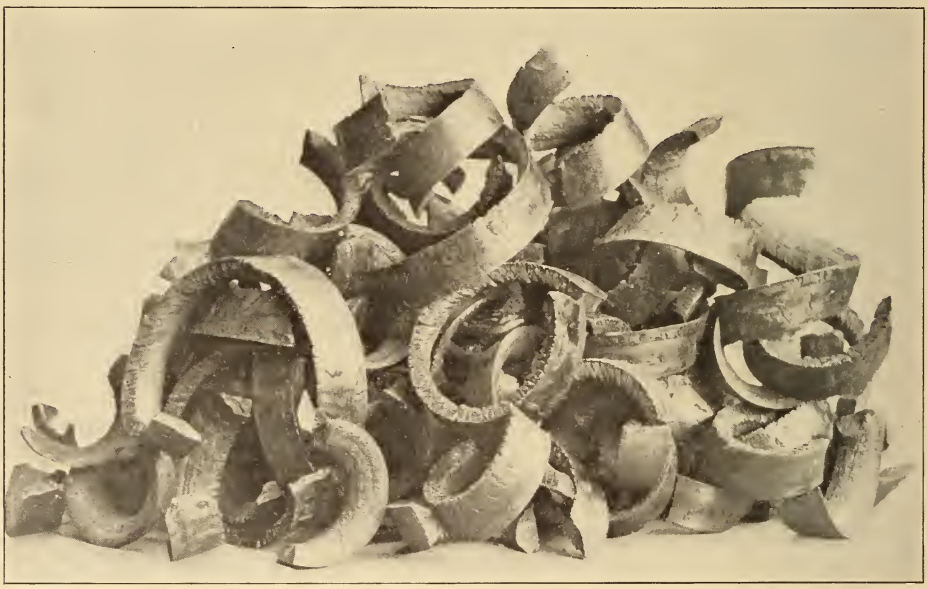


FIG. 21.—"SPEEDICUT" TOOL STEEL RESULTS. TURNINGS REMOVED FROM A STEEL FORGED BAR AT A CUTTING SPEED OF 51 FEET PER MINUTE. DEPTH OF CUT, $\frac{3}{8}$ INCH; FEED, 1-10 INCH PER REVOLUTION; DURATION OF CUT, 30 MINUTES; WEIGHT OF METAL REMOVED IN THAT TIME, 207 POUNDS

Some of the illustrations accompanying this article show samples of steel turnings produced at the Cyclops Works of Messrs. Cammell, Laird & Co., Ltd., of Sheffield, which

FIG. 22.—A "SPEEDICUT" STEEL TOOL

I have had arranged and photographed alongside common objects,—as a rule, a pencil and a shilling, for the purpose of affording comparisons. Figs. 18 and 19 are remarkable from the fact that the turnings were taken off at speeds ranging from 50 to 60 feet per minute. In all cases only one tool, made from Cammell-Laird steel, was cutting at a time. The material of the turnings is mild steel, cut from a locomotive axle.

The two striking views, Figs. 20 and 21, of turnings removed by "Speedicut" steel, made by Messrs. Thomas Firth & Sons, Ltd., of Sheffield, represent the two conditions of working around which so much discussion arises,—that of high speeds with light cuts against medium speeds and coarse cuts. The particulars given below each illustration will permit of comparisons being made.

The duration of the cut was 30 minutes in each case and the speed was practically the same. The coarse chips were removed to the enormous amount of 660 pounds in 30 minutes; of the light chips, 207 pounds were taken off. In both cases the tools were in perfect condition at the termination of the experiment. The use of a lubricant favours the greater result in some degree.

Messrs. Firth attach much importance to the shape of the tool used, a view of which is given in Fig. 22. They say that it is a mistake to give a tool intended for heavy duty side rake right up to the cutting edge. They prefer to bring the rake nearly but not quite to the edge. They also bend the bar to bring the cutting edge at an angle of 20 degrees from the straight shank.

This "Speedicut" steel is used largely for drills and milling cutters with wonderful results, though we cannot enter into the discussion of the steel deeply in this article.

A tool made from the "Novo" steel of Messrs. Jonas & Colver, Ltd., of Sheffield, is illustrated. This steel is used largely in America as well as in Great Britain. This particular tool was used, and ground down from time to time without reforging, from the full to the dotted lines, doing good work all the while.

With the growth of high-speed work, it will be more desirable than heretofore to provide on every lathe a table of revolutions for all the com-

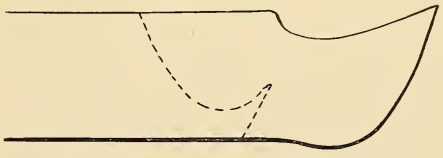


FIG. 23.—TOOL MADE OF "NOVO" STEEL BY MESSRS. JONAS & COLVER, LTD., SHEFFIELD

binations of cones, gear ratios, and countershaft speeds obtainable. This is more necessary with high-speed steels than with ordinary steels, as experiments prove that they can be

safely run very close to the point at which failure occurs. It is not much use to let a workman know that certain speeds, under certain characteristics of tool and material are the best, if he is unable to ascertain at once the speeds at which the work is running without having to use a speed indicator or such device. This will probably lead to the growth of instruments for working out the speeds obtained.

An example is the Barth speed slide rule, which comprises two superimposed circular discs. The upper and smaller one turns on the lower, around a central stud. The lower disc contains three circles of figures which read feet per minute, turns of work per minute, and ten turns in a fraction of a minute. The figure on the top disc which corresponds with the diameter of a piece of work is set opposite the rate of turning in feet per minute. Then an arrow head on the upper disc points to a figure which shows the number of turns the work must make to produce a 40-foot rate of cutting, and alternatively another arrow points to the fraction of minute in which the work should make ten turns.

In another form of this rule the outer readings are replaced by another set which shows the arrangement of belt and back gears for any machine that comes nearest to giving the exact speeds required.

Current Topics

From the standpoint of the traveling public, few aspects of modern railway operation better indicate the progress of the last decade than the service rendered by high-speed trains. As the pressure of urban life has increased, time has grown more and more valuable, so that the importance of saving it for productive work has become widely appreciated, particularly among that class of business and professional men who represent the executives and advisory experts of industry. Hence, to cite a specific case, the saving of a business day in the thousand-mile trip from New York to Chicago, through the adoption of a 20-hour and then an 18-hour schedule, is rightly considered an achievement thoroughly in harmony with the temper of the times. It is well to thus broadly think of the matter, in reflecting upon the recent disastrous accident to the "Twentieth Century Limited" train running between the above-men-

tioned cities. In the light of present knowledge, it does not appear that the fast schedule of this famous train was in any sense the cause of the terrible disaster which overtook it. Experience has shown that some of the worst railroad wrecks have occurred at speeds of 30 miles an hour or less, and although the magnitude of damage effected by a collision or a derailment is reasonably liable to be greater at high speeds than at low ones, it does not always follow that the loss of life and property in a wreck at 40 miles an hour will be less than the casualties sustained at 60.

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THE unexpected happens in railway accidents as perhaps nowhere else, and so obscure are the causes which produce the results, that no man can say where the line is to be drawn between safe and unsafe speeds. Even if it were certain that serious accidents were out of the question at 20 or 25 miles an hour, the pressure of modern life would not tolerate such speeds for a single day. Some risk must always be attached to fast traveling, regardless of the means employed, but it is none the less incumbent upon transportation experts to adopt every possible method and device to secure safety. Each disaster occurring should teach a lesson never to be forgotten, and terrible as the cost of such learning is, the operation of railways ought to be carried on in a safer manner ever after, as far as the preventable features of the catastrophe are concerned. As long as human nature is fallible and human knowledge finite, some accidents are certain to occur; but there is little excuse for failing to press home the lessons of experience, and leave no stone unturned to secure the highest possible degree of immunity.

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THE striking lesson of the wreck of the "Twentieth Century Limited" train is the enormous importance of eliminating facing-point switches from main lines. Doubtless in certain track lay-outs it seems almost impossible to do this, but in the light of the disaster it seems imperative that this precaution be taken on all lines, and at all points where the speeds approach those common in express train service. In cases where the facing-point switch cannot be dispensed with, some form of automatic signal capable of indicating the condition of the switch at a safe stopping distance is an absolute necessity. It is also a question if very high speeds should be permitted in even the best designed special track work entangled with the main line. Finally, it is worth while to consider if it would not be better to build cars more nearly fire-proof externally, for use on very fast trains, than to continue to use wood in such quantity that a conflagration almost always grows out of a telescoping wreck or collision. It is impossible not to think of the electric locomotive in this connection, with its lesser danger of fire on account of the absence of furnace and boiler. It is to be hoped that the result of the disaster here specially referred to will be, not to permanently slow down fast schedules, but to render high speed safer than ever before.

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REFERENCE has been made in these pages several times to the fact that horse-drawn fire-engines are among the things distinctly discreditable to twentieth century methods. With automobiles of all types as examples of what excellent results can be accomplished in the line of self-propelled vehicles for ordinary roads, the wonder is, indeed, that the self-propelled fire-engine is so slow in making progress; or, to put things more correctly, that the average municipality is so slow in giving it proper recognition. Recently, however, the important announcement

came from Vienna that the municipal authorities there had decided to re-equip their professional fire brigade, together with the auxiliary suburban volunteer fire brigades of that city, entirely with motor appliances. The first step in this direction, according to "Engineering," of London, is an order for no less than 53 motor chemical engines and traps, to replace the horsed chemical engines and traps of the professional service, and those of the volunteer auxiliary brigades who have their own horses. When this part of the work of re-equipment is completed, a decision will be arrived at as to replacing the horse steam fire-engines and horsed mechanical long ladders by self-propelled vehicles, or adapting them to motor traction. The Vienna Fire Service has long stood as a model on the Continent for its modernity of ideas in matters of equipment, and it is only about ten years ago that its entire equipment of manual fire-engines was replaced by pneumatically-raised 80-foot long ladders. In each case the provision of the new appliances meant the immediate scrapping or sale of the old appliances, so that no old lumber in the way of appliances is to be found at the Vienna Fire Brigade stations. The present step is, however, probably one of the most important in the annals of the world's fire service, and it certainly will greatly influence the efficiency of the Vienna service. As to the financial aspect of the first order of fifty-three appliances, it is highly interesting to observe that the Vienna Fire Brigade budget shows that there will be a saving of 76,000 krone (£3166) per annum, and that as the new appliances involve a capital outlay of 850,000 krone (£35,-416), the whole of the new and more efficient appliances will practically be paid for out of economies in something like eleven years. That motor appliances, when worked in numbers, mean a considerable economy was proved by experiment at Vienna prior to arriving at this decision, and it has been equally proved in Hanover, where experiments with a number of motor fire appliances have been carried out for the past three years. The same experience is understood to have been obtained in Liverpool. It is another matter of interest to see that the Vienna Fire Brigade has adopted electrical propulsion for its chemical engines and traps. Regarding the steam fire-engines, the mode of propulsion has not yet been decided upon, but it will probably be by steam.

WHAT is thought to have proved to be the most economical steam engine ever built was recently tested in Belfast, Ireland. A full report of the test recently given in "The Engineer," of London, shows that the lowest steam consumption per horse-power per hour was 8.585 pounds, obtained in one of a series of runs, although nearly as good results were obtained in two other tests, and all were excellent. The engine was one built by Messrs. Cole, Marchent & Morley, of Bradford, England, rated at 500 H. P. at 100 revolutions per minute, with a steam pressure of 120 pounds. The engine was installed for the Durham Street Weaving Company, Ltd., Belfast. The report of the test was made by Michael Longridge of the British Engine, Boiler & Electrical Insurance Company. The engine is an inverted vertical cross-compound marine type, and has a reheating receiver between the cylinders. The latter are unjacketed. The valves are of a drop piston pattern, which seems to possess the advantages of the drop valve and Corliss valve without their disadvantages, and may be satisfactorily lubricated. In constructing the engine it was the aim to take advantage of a superheat of 700 degrees F. The makers claim that from their experience it has been found that the Corliss valve is unsuitable for temperatures above 500

degrees F., and, so far as is known, no engine with true Corliss valves has ever been operated satisfactorily at anything like 700 degrees F. superheat. The test was conducted with extreme care and may be taken as of unquestionable accuracy. The steam consumed was measured by weighing the discharge from the condenser by the two-tank method, one being weighed while the other was filling. As all parts were steam-tight it was unnecessary to allow for leakages at valve spindle or piston rod glands. The cylinders were, respectively, 21 and 36 inches in diameter by 36 inches stroke, the ratio between the high and low being 1 to 2.984. By virtue of the valve gear the makers claim that the engine can be run faster than would be safe with either the drop valve or the Corliss valve, the limit in most cases being decided by the piston speed rather than the valve gear. Each cylinder has four piston valves, one at each end to admit steam, and one at each end for exhaust. The steam valves are opened by eccentrics and closed by springs through a trip gear. The cut-off on the high-pressure cylinder is controlled by the governor, and on the low pressure by hand. The exhaust valves are opened and closed by eccentrics. The steam is supplied by a Lancashire boiler and superheated in an independently-fired Schmidt superheater containing 1033 square feet of heating surface, and 11½ square feet of grate surface. The engine was said to have been in operation over a year and ran very satisfactorily during the trials without a leak anywhere and with every bearing cold. After stopping, one of the high-pressure steam valves was taken out and found to be in perfect condition throughout. The conclusion is that no trouble need be anticipated from the effects of high superheat upon the valves; nor is there any probability of trouble when the steam is once within the cylinder, as there it will not be much hotter than high pressure saturated steam. If any trouble is to be expected, it may be looked for in an effect of the high temperature upon the tubes of the superheater, although no such trouble has yet been experienced.

Smokeless powder and smokeless boilers are coupled by Mr. Horace See in a recent letter to "The Army and Navy Journal," discussing naval efficiency. "The use of the smokeless powder is general," says Mr. See, "while that of the smokeless boiler, notwithstanding its many-sided advantages, is extremely limited. The value of the former is fully recognized, while that of the latter is only partially so. No artillerist would to-day suggest the use of the old-fashioned explosive, which not only envelops to a greater extent with smoke the gun from which it issues, but also fails to produce an amount of energy equal to that with the new agent. In the case of the boiler, however, a different state exists. Although it is possible to construct one, whether of the fire or water-tube variety, that will operate comparatively free from smoke, while generating more steam on the same amount of fuel and thereby increase the steaming radius of the vessel from 10 to 20 per cent., we find it conspicuous by its almost total absence. The value of such a boiler cannot be overestimated, particularly in a war vessel, as the fuel so saved and remaining in the bunkers, after covering all the ground possible with a boiler that smokes, may mean one or more days' additional steaming, and thereby make possible the wrenching of victory from defeat, not only in the case of a single vessel, but also of an entire squadron. If, then, a smokeless boiler is possible, why is one that is not free so common in our navies; why do so many pour out such volumes of unconsumed carbon from their stacks when the vessel is in motion, to betray not only its location, but also

hide it to such an extent that signals on it or from it cannot be seen, and why is the fuel—so important a factor in the endurance of the vessel—unnecessarily wasted? The most charitable answer is that the fault has either escaped attention, as the vessels, of all navies are handicapped in the same manner, or has not been considered sufficiently serious to warrant the adoption of a boiler of a more perfect type. To show that the smokeless boiler is a rara avis in the vessels of the world's navies, it. is only necessary to call attention to the various published representations of the fleet of Admiral Rojestvensky in the illustrated journals, to the many of vessels of the different navies, and last, to the report of the changing of the position of the flagship of one of our squadrons on account of its signals being hidden from the other vessels of the fleet. To learn that it is not impossible to construct a smokeless boiler it is only necessary to pay a little attention to the vessels steaming in and out of New York harbour and note some of the great ocean liners and the coastwise vessels of lesser tonnage coming in and going out with but little exhibition of smoke issuing from their stacks, and this, when seen, only in puffs at intervals on leaving the harbour."

At least one of the accidents that have thus far occurred in the New York Subway has been of value in bringing into prominence the merits of all-steel car construction in the case of rear-end collisions. In this accident a local train had stopped at a station, and the following train ran into the rear coach at a speed of about 15 miles an hour. The rear car of the stationary train and the front car of the moving train were of steel construction. Owing to a delay in filling a large order for these steel cars, only two of them were used at the time on each local train, one being placed at the front, and the other at the rear, with wooden cars intervening. Neither of the two steel cars which bore the brunt of the collision was appreciably damaged, and none of the passengers in them was harmed. The wooden cars, however, were telescoped, and several of the passengers in them were seriously injured. The results of this accident highly coloured the arguments in favour of all passenger cars being constructed of steel, many adherents to this principle going so far as to say that with them there would be no further danger to human life through rear-end collisions. Although it has been demonstrated that collisions between trains composed of both steel cars and wooden cars result in little, if any, damage to the steel cars and their occupants, it does not by any means follow, however, that a collision between trains composed entirely of steel cars would mean the same immunity from death or injury that the occupants of steel cars have hitherto enjoyed.

The excellent showing thus far of steel cars in collision is made possible by the wooden cars forming a part of the trains; the wooden cars, being weaker than those of steel, act as cushions, and by becoming crushed, modify the force that otherwise would be exerted upon the steel cars. If trains were composed entirely of steel cars, all of approximately the same strength, it is probable that these cars would in certain collisions be crushed or telescoped,—at any rate, they would certainly not carry off the honours which now are literally thrust upon them. But it is not intended to discourage the exclusive use of steel cars on passenger trains. The great est good is that which benefits the largest number of people, and in no direction could all-steel car construction be better applied than on the steam railways, where, according to present conditions, Pullman passen-

gers are made safe from collisions on account of the greater risk incurred by the occupants of the day coaches. In connection with this it must also be remembered that the use of steel cars would reduce to a minimum the fire risk which so often adds to the horrors of a collision. The New York Subway accident mentioned in these paragraphs has, by the way, brought out the usual popular suggestions, more or less fanciful, as to the avoidance of disastrous end-on collisions. One of them has favoured the employment at the front and at the rear of a train of some form of car specially designed to take up and dissipate the shock resulting from a collision. This car would not be intended for passengers, as it would be made most efficient by being designed to crush or telescope, so as to offer a gradually increasing resistance to the force of a collision. It recalls a device, presented to the Patent Office fifteen or twenty years ago, providing for the arrangement of a set of powerful buffer springs at the head-end of every railway train, these springs to take up the shock of head-on collisions.

But it is a bit strange not to have been told by someone that now is the time to put to good use the over-running or under-running railway train idea which has been bobbing up every now and then for many years past, and is now, with modified working details, in practical working form at America's mammoth sea side pleasure ground,—Coney Island. There it is very aptly called the "leap frog" railway. The problem to be solved was the interesting and oft-recurring one of how to enable two trains to pass each other on the same track without collision. The fundamental scheme, as previously outlined in these pages, was to place on the front of every locomotive going in one direction a long inclined plane, and on this were to be two rails. These were to come close to the regular track at the forward and lower end of the plane, and at the upper end they were to be connected with other rails running along the tops of the cars and down again to the main track on another inclined plane at the rear end of the train. When a train with this attachment meets another train on the same track, the latter will simply go over the former. As in the case of all really great ideas, the only startling thing about it is simplicity, and after thinking it over, one wonders why so much money has been wasted on double-track lines.

A considerable financial loss to machine tool manufacturers recently, resulted in a certain locality from a curious, though not unprecedented, coincidence of atmospheric conditions. The weather, as told in "The Iron Age," had been cold, so cold in act that workmen experienced considerable discomort in the shops, and at the same time the humidity was unusual. Within the few hours from 11 A. M. to 2 P. M. the mercury rose more than 40 degrees. Heavy pieces of metal then began to sweat, not slightly, but in great drops, as if rain were falling upon them. Thinner pieces of metal experienced little of this, because they soon took the temperature of the atmosphere. Heavier pieces, warming slowly, presented an appearance the like of which few foremen or workmen had ever seen. At first the danger of the ruin of finished surfaces from oxidation was not realized. In one large shop, however, the manager, who chanced to be in the works, impressed the menace upon the minds of his employees. The moisture, with which the air was heavily laden, condensed with extreme rapidity, so that from a large surface the drops were scraped by the hand, to fall with a splash upon the floor, only to be replaced almost instantly by as watery

a condition. Parts of machines in process of manufacture, and parts of the machines of the shop equipment were in imminent danger of serious rusting. The shop force went to work with much vigour. The only method that succeeded was to wipe away the moisture and instantly apply a coat of slush. This was done as far as possible, but many finished surfaces were damaged, either by a complete layer of the rust or by spots. Consequently considerable expense was entailed in refinishing such surfaces. The trouble was by no means confined to this one shop. Many machine builders suffered, some more seriously than others.

Fortunately, remarked "The Iron Age," such a circumstance is rare, for it is seldom that so extreme a change in temperature is experienced, especially when coupled with a humid atmosphere. Happily, also, smaller parts and shell-like pieces like hollow cylinders do not suffer because they quickly take the atmospheric temperature and there can be no condensation. To illustrate this, one large cylinder, perhaps 18 inches in diameter and $\frac{3}{4}$ inch thick, was not touched by rust, while large solid cylinders a few feet from it were seriously affected. If a portable steam blast were at hand or artificial heat given the exposed metal by some means, it would not suffer, of course; but in the machine shop such apparatus would be seldom available. In the winter, where a shop is kept heated at a somewhat constant temperature—at any rate, at a temperature within limits so that there can be no extreme variation of temperature within a few hours—humidity may be disregarded. The only remedy when the condition does exist, as it must at times in a climate where extremes of weather are frequent, is to act quickly and intelligently, remembering that exposed finished surfaces must be given a moisture-proof covering. Perhaps it would be well to prepare for such an emergency, as soon as a cold, damp spell of summer weather makes its appearance, by a generous use of slush. Of course, there is always the danger of comparatively trifling losses occasioned by an extreme dampness of weather, especially on the seaboard, where fogs are prevalent. But it would take not a few such occasions combined to equal the serious effects of the instance here noted.

In an address before the American Society of Mechanical Engineers several months ago, dealing with "Some Refinements of Mechanical Science," Mr. Ambrose Swasey, speaking of the measurement of time, said that the sun dial is not only the earliest, but the most interesting, of all the numerous arrangements devised for measuring the divisions of the day. Notwithstanding its limitations, it has been a subject which has attracted the brightest minds for ages. Within these later years there has been a renewed interest in this ancient timekeeper, not only in copying the types of dials, which are valuable because of their antiquity, but in working out new forms. Recently a new dial was invented, by which the rays of the sun will indicate the true mean time for each day of the year, with an error not to exceed one minute. The hour glass, which came later, was considered a much more practical method, inasmuch as it could be used either day or night, and because its use was not confined to a particular location; however, as a timekeeper it was not satisfactory, even in those early days.

The clepsydra, or water clock, which is supposed to have been invented by the Greeks, was found to be a much better timekeeper than

either the sun dial or hour glass, and it was a great step in advance toward the accurate measurement of time. These water clocks are to this day used extensively in the East, more especially in China. Those first used by the Greeks consisted of two water jars so arranged that the water from the upper ran into the lower, and the time of day was determined by measuring the depth of water in the upper jar, and at sunrise each day the water was returned to the upper jar. In the city of Canton there is a water clock which has been running for eight hundred years, and at the present time it is the standard clock of that city. This clock consists of four water jars, each having a capacity of eight or ten gallons. The jars are placed one above the other, in the form of a terrace, the three upper ones being provided with a small orifice near the bottom, through which the water drops into the jar next below, and so on down from one to the other, until the water reaches the lowest or registering jar. In this there is a float, to which is attached an upright, having graduations for the hours and parts of hours, and as the water rises, the time can be determined by noting the height of the float in relation to the cross-bar at the top of the jar. In this improved form of water clock the variation in the flow of water, due to the difference in height, is overcome by having a series of jars, the outlet of the upper being so graduated that there is but little variation in the height of water in the second jar, and in the third the height remains practically uniform, thus insuring a constant head for the water which drops into the registering jar. At the beginning of each day the water is taken from below and carried up a flight of steps to the top. That such an arrangement has some elements favourable to the accurate measurement of time, there can be no doubt. It certainly has the element of simplicity, and notwithstanding its long service, the only wear noticeable was confined to the steps leading to the upper jar.

While a great many engineers will probably agree that the best thing to do with old boiler tubes is to throw them away and get new ones, Mr. D. E. Rust, in "Mines and Minerals," suggests that a comparatively trifling sum spent in cleaning them and attaching flanges, will make of them excellent air or water pipes, which can be used where the pressure carried does not exceed 75 or 100 pounds per square inch. Wherever compressed air is used or water is to be pumped, the outlay for pipe is one of the large items of expense, and when used underground, only a small percentage of this pipe is returned to the surface in a serviceable condition. A year or more ago, according to Mr. Rust, the company with which he is connected had several hundred old boiler tubes, mostly 3 inches, $3\frac{1}{2}$ inches, and 4 inches in size and 16 to 18 feet long, which were considered practically useless until experiment proved their value as pipe. Threads and couplings, Mr. Rust says, cannot be used with success for joining the various lengths, for two reasons:—First, the old tubes are usually too thin to allow for the threads, and secondly, they are apt to be out of a true circle. Flanging is therefore the best method for this purpose.

If plumbers lived up to their name, remarked Mr. James M. Healey recently, at the Indiana Master Plumbers' Convention, they should know little or nothing about iron pipe work, since the word plumber means, primarily, "a worker in lead," and the day is not far past when the plumber's skill as a craftsman was judged entirely by his ability to construct every required form of lead work. Latterly, machine-made traps

and bends, and the substitution of cast iron in place of lead soil pipe, have changed in some degree the art of the plumber, although it still holds good that lead work is the distinctive province of the plumber. The changes mentioned have come to stay, and most of us would not, if we could, go back to the primitive methods of hand work. We are willing also to admit that lead soil pipe, because of its weight, was liable to sag and lose its shape, and that a source of danger lay in its liability to be punctured by nails or gnawed through by the pestiferous rat. Cast iron soil pipe is not subject to these dangers, and, happy thought, it must still be jointed with a lead calk, with the chances all for cracked hubs or open joints if a tinker attempts to do the calking. The plumber is still needed to run a stack of soil pipe, and he must be a good plumber if the stack is to be run in good and workmanlike manner.

For water-supply pipes, range-boiler connections and exposed wastes and overflows, continued Mr. Healey, lead pipe, not iron pipe, is the proper material. There is something more than trade jealousy back of our contempt when we apply the epithet of "iron-pipe plumber" to the tinker who tries to break into the trade by the back door of the screwed fitting, rather than by the front door or the wiped joint. Iron pipe is not a suitable material for the purposes I have mentioned for several reasons which will readily occur to any one who stops to give the matter a moment's thought. Iron, when unprotected, is liable to rust, thus contaminating the water which flows through supply pipes of this material, or, when iron pipe is used for wastes or overflows, endangering the whole system by stopping up of the pipes with rust, or by offering a means for the escape of sewer gas through scarcely visible but none the less dangerous rust holes. The use of galvanized pipe on supplies is to be condemned, because of danger of poisoning the water. Experience has shown this to be a very grave danger and one to which the plumber should not permit the householder and his family to be subjected, no matter how great the desire to practice a false economy. For exposed work, nickel-plated supplies and wastes are deservedly growing in favour, while for high-class residence work, brass soil and waste pipes are finding a limited use. With this condition of things, however, we should have no quarrel, for on this class of work a tinker does not get a chance to bid. But for all-round utility in the plumbing of all sorts and conditions of houses, lead pipe still remains the plumbers' old reliable standby, and I predict that it will be many years, perhaps many generations, before the plumber will cease to be, as he has always been throughout the thousands of years in which he has plied his honourable craft, a worker in lead.

In discussing the use of gas as a fuel for hot-air heating in the conventional type of hot-air furnace so much in favour all through the United States, R. S. Thompson, in a recent paper read before the American Society of Heating and Ventilating Engineers, said that one of the most difficult problems in connection with it is the disposing of the water of condensation which results from the combustion of the gas. A thousand cubic feet of gas weighs about 37 pounds, and, if of high quality, contain from 9 to 11 pounds of hydrogen, but as each pound of hydrogen in the gas combines during combustion with 8 pounds of oxygen from the air, there is a production of 9 pounds of water for each pound of hydrogen contained in the gas, and 1000 cubic feet of good gas will thus produce from 80 to 100

pounds of water when burned. To allow this water to escape in the form of steam at a high temperature involves a great waste of heat. To utilize this heat by cooling the products of combustion to the point where the steam will be condensed involves the problem of disposing of the water of condensation. By proper construction of the burner and regulation of the air supplied to the fire, a large portion of this water can be mechanically carried off through the chimney in the form of mist which is suspended in the air after the latent heat has been removed, but some of it will, under some conditions, form into drops, run down the inside of the chimney and drop from the furnace. Therefore every chimney used for a gas fire should be perfectly straight and lined with tile, and provided with an opening at the bottom for the escape of the water.

In several cases mentioned by Mr. Thompson, he provided for gas furnaces special chimneys made of gas pipe from 3 to 6 inches in diameter, according to the size of the furnace, with a $1\frac{1}{4}$-inch pipe at the bottom connected with a drain. The furnace itself should be provided with some small openings to drain off the water, though, of course, the arrangement of these will depend on the construction of the furnace. In the case of one furnace which had proved troublesome, the difficulty was found to be that the lower flues had become completely filled with water. In another case the furnace was connected with the chimney by means of a smoke-pipe 35 feet long. This pipe near the chimney was close to a window, and owing to the fact that the window had carelessly been left open, the pipe at that particular point had become entirely closed with ice. Mr. Thompson further calls attention to the fact that most gas contains sulphur, and this, when burned in connection with hydrogen, produces sulphuric acid. The water of condensation is, therefore, usually quite corrosive. It will eat the mortar out of chimneys; hence the necessity for lining them with tile. It will also corrode iron, so that the smoke-pipe should be of heavy iron and coated inside and out with some acid-resisting paint.

GEORGE GIBBS

A BIOGRAPHICAL SKETCH

With the recent resignation of Mr. George Gibbs as vice-president of the well-known engineering firm of Messrs. Westinghouse, Church, Kerr & Company, and also as consulting engineer of the Interborough Rapid Transit Company, both of New York City, to become chief engineer of electric traction for the terminal operation of the Pennsylvania Railroad in New York City, and chief engineer of electric traction for the Long Island Railroad as well, an opportunity is afforded of congratulating these companies upon securing the services of so competent an engineer.

Mr. Gibbs graduated in 1882 from Stevens Institute of Technology, Hoboken, N. J., with the degree of Mechanical Engineer, and since then has had a varied engineering experience, fitting him peculiarly well for his new duties. During the two years following graduation, he worked as chemist for the Orford Copper Com-

pany, of New York, and immediately thereafter became engineer of tests, and chemist, for the Chicago, Milwaukee & St. Paul Railway Company, of Milwaukee, Wis. From 1888 to 1897 he was mechanical engineer for the same road, and had charge of their car and locomotive designing, and also of their interlocking and track signals.

Between 1897 and 1902 Mr. Gibbs was consulting engineer of the Baldwin Locomotive Works and of the Westinghouse Electric & Manufacturing Company. He was also chief engineer of the British Westinghouse Electric & Manufacturing Company, Limited, and of the Continental Westinghouse Companies.

Since 1901 he has been first vice-president of Messrs. Westinghouse, Church, Kerr & Company; consulting engineer of the Interborough Rapid Transit Company, of New York City; member of the board of engineers on tunnel lines and terminals of the Pennsylvania Railroad Company, of New York; member of the Electric Traction Commission of the New York Central & Hudson River Railroad Company, and electrical engineer for the Long Island Railroad Company.

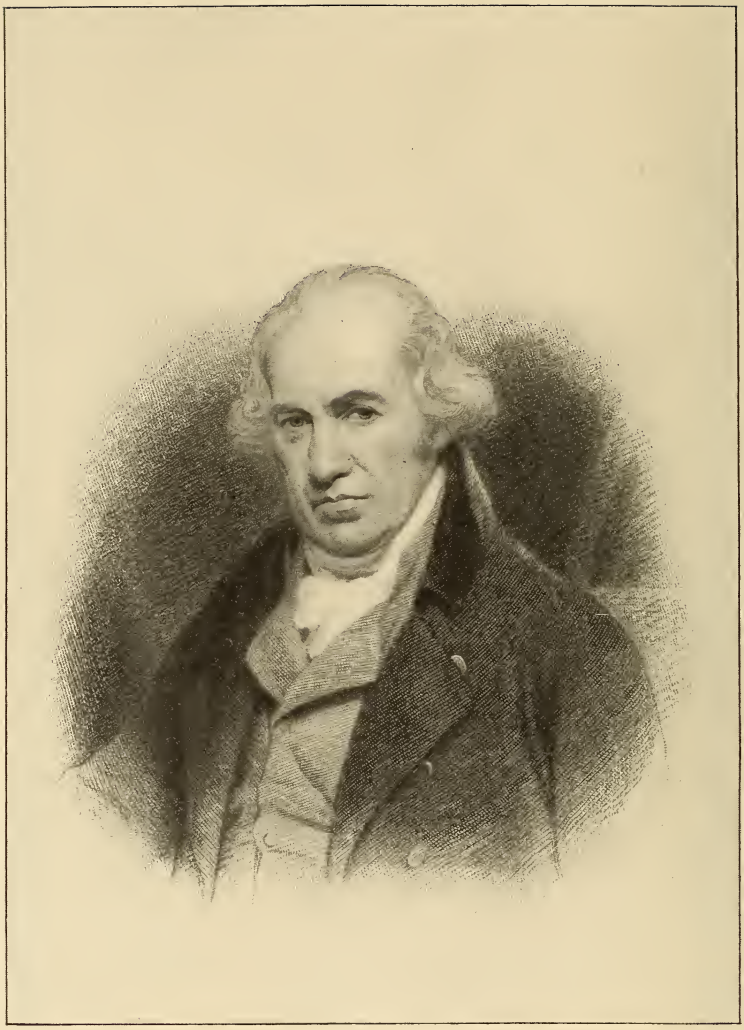
In connection with the Interborough Rapid Transit Company's operations, he had charge of the designing of rolling stock, track work, interlocking and signals, shop yards and repair plants, but with the completion of the New York Subway this work practically came to an end. While engaged in Interborough work, Mr. Gibbs designed for this company the first steel passenger cars in the world. The over-lapping block signal system for congested train movement was also first applied by him in America.

With the Pennsylvania Railroad Company he had special charge of the electric power plants, electric locomotives, the power distributing system, and the mechanical engineering features of the terminal yards and buildings. With the New York Central & Hudson River Railroad Company he was engaged in electric traction work, the equipment of heavy electric locomotives, power plants, and the distributing system.

In his new position with the Pennsylvania Railroad Company, Mr. Gibbs will have charge of all the electrical and mechanical engineering work, the designing and execution of work in connection with their tunnels, yards, terminals, power houses, etc., in New York, and he will undoubtedly be a prominent factor in any other of the electric traction schemes which this company may undertake during his connection with them.

In connection with the Long Island Railroad Company he will have charge of the designing and installation of all electric traction work which that company is now doing or has in contemplation. One may form an idea of the scope of his future labours with this company from the fact that what has already been put in by them constitutes the largest electric traction project on any steam railway in the world.

In addition to the heavy responsibilities thus assumed, Mr. Gibbs has also accepted the position of consulting engineer of the Metropolitan Railway Company interests in their proposed subway work in the city of New York. He is also confidential adviser in engineering in the Carnegie Institution at Washington, D. C., and a member of the following organizations:—The American Society of Civil Engineers; the Institution of Civil Engineers, of Great Britain; the American Society of Mechanical Engineers; the American Institute of Electrical Engineers; the American Railway Master Mechanics' Association, and the Master Car Builders' Association.



JAMES WATT

BORN IN 1736. DIED IN 1819.

Engraved by W. Holl after the Portrait by Sir W. Beechy, R. A.

INDEXED

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THE TRUCE BETWEEN CAPITAL AND LABOUR

By Carroll T. Fugitt, Director of the Welfare Department of the National Cash Register Company, Dayton, Ohio, U. S. A.

THE city and citizens of Dayton, Ohio, U. S. A., on July 31, of this year, gave a tremendous public reception to Mr. John H. Patterson, returning from a year's journey around the world. Forty thousand men and women—nearly half the city's population—took part in it. The stores and factories closed an hour before his arrival. The Mayor voiced the city's welcome. One hundred of the leading manufacturers, merchants, and professional men with a special train met the city's guest a hundred miles down the line and escorted him home in state.

A huge loving-cup, purchased by popular subscription, was presented by the citizen's committee. The women of Dayton claimed a place in the programme to offer an illuminated address hailing Mr. Patterson as "the apostle of women's welfare." Even the public schools which had felt the influence of Mr. Patterson's interest played a part in his home-coming, a chorus of three hundred children chanting songs in his honour.

Dayton's welcome to Mr. Patterson was all the more notable because he had never held a public office of any sort, and in his efforts towards municipal betterment he had fre-

THE NATIONAL CASH REGISTER COMPANY'S EMERGENCY HOSPITAL. TWO TRAINED NURSES ARE ALWAYS ON DUTY, AND A PHYSICIAN IS WITHIN CALL

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THE MAIN GROUP OF FACTORY BUILDINGS IS CONNECTED BY BRIDGES AND TUNNELS

quently come into collision with the local political "bosses." When a man's neighbours, too, shut up shop and line the streets in honour of the work he is doing, it is well for strangers to ask the reason.

In Mr. Patterson's case it was frankly set down to the welfare work which he had done and is doing for the 3800 men and women in his employ as the president of the National Cash Register Company. The welcome of the people is explained by the fact that nearly every wage-earner in Dayton lives and works in greater comfort because Mr. Patterson has shown the manufacturers of the city, as well as of the country, how easy and profitable it is to get factory conditions right.

Welfare work according to Mr. Patterson's idea is co-operation. "Labour and capital working together, for the benefit of both," he defined it for the great audience which listened to the city's address of welcome and his own response. At the National Cash Register factory, his ideal has come very near to realization. Beginning with the company's effort to make work healthful and pleasant, the work has been taken up and extended by the employees on their own account. The Men's Welfare Work League, with 2500 members, and the Women's Century Club, with 600, have supplemented the company's work in admirable fashion and have made their influence felt, not only in the schools and factories of Dayton, but in all parts of the United States.

National Cash Register welfare work has three things for a basis,—healthful working conditions, pleasant surroundings, and educational opportunities. The healthful working conditions began with huge, airy work rooms, perfectly lighted and ventilated, and scrupulously clean. The pleasant surroundings include smooth green lawns, bounded by shrubbery, vine-covered buildings, and a neighbourhood made beautiful with trees, vines, and flowers. The educational opportunities embrace schools and classes of many kinds for employees, lectures by prominent men and women, a well-stocked library, literary and social clubs, and educational trips to other factories, to expositions, to the great cities, and even to Great Britain and the Continent.

The growth of welfare work at Dayton has been gradual. It began in the conviction of President Patterson that attention to the health and comfort of his employees was not only his duty as a man, but also his best investment as a manufacturer. Again and again he has given this terse reason for extending the work, —"It pays."

His first step in welfare work was the beautifying of the factory premises. Fifteen years ago the National Cash Register factory was a modest little plant in no way different from a thousand similar factories in America. It was fenced in by ugly palings, and the workers within looked out upon a landscape of cinder heaps, broken crates, boxes and other rubbish.

As a beginning the fences were torn down and a small lawn was laid out before the main building. Then a few flowers and shrubs were added. As the business grew year by year, the finest group of factory buildings in the world was erected. The first demand on the architect was for the maximum of fresh air and sunlight. Mr. Patterson knew that both air and sunshine were necessary for the health and happiness of his people. He had decided, too, that to get the best results both from man and machinery, the working conditions of the man must be looked after as carefully as those of the machinery.

The wide windows of the new factory drew the fire of the disorderly

WIDE WINDOWS IN THE FACTORY WALLS LET IN SUNSHINE AND FRESH AIR

LAST YEAR NEARLY TEN TONS OF VEGETABLES WERE HARVESTED BY THE NATIONAL CASH REGISTER BOY GARDENERS

boys of the neighbourhood. They broke the panes and damaged the machinery. They pulled the flowers, trampled down the grass and tore up the shrubbery. The problem of how to stop this nuisance was solved by Mr. Patterson. He called the boys together and told them about his boyhood on a farm when he had helped to plow the ground on which the National Cash Register factory now stands. He challenged their interest and then provided vegetable gardens for forty of them.

The company furnished the ground, the tools, seeds, and an experienced instructor. The boys did the planting and cultivating, and harvested the products and the profits. Prizes were awarded for the best results. The boys were enthusiastic from the start. They forgot the delights of window-breaking, and the National Cash Register Boys' Gardens have grown each year, both as a neighbourhood and a national institution. Last year there were seventy-two gardens, and the young farmers harvested nearly ten tons of vegetables from their plants.

To secure the co-operation of the people of the neighbourhood, the South Park Improvement Association was formed. By means of stereopticon talks on landscape gardening the people were taught how a few vines would cover and beautify fences and sheds, how window boxes and lawns should be arranged, how ugly back yards could be transformed into attractive gardens. The company offered prizes to those who made the most marked improvement in the appearance of their places. In a short time the National Cash Register neighbourhood, long known as "Slidertown," became known as "South Park." Now it is one of the "show" quarters of the city, and the value of property has more than doubled as a result of the work.

Nothing in National Cash Register welfare work has done more to improve the factory standards, and to promote the individual happiness of employees than this neighbourhood

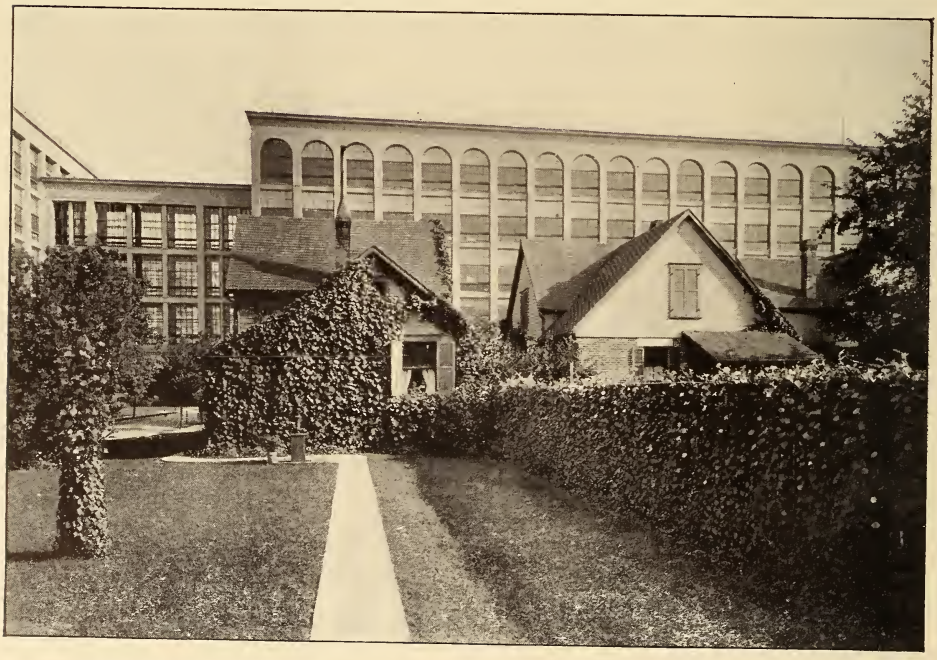
betterment. A workman in a dark, dirty shop, with narrow, unwashed windows, chafes under the discomforts, even when he is not acquainted with anything better. There is a loss of energy, lack of inspiration, and a consequent falling-off of interest in his work. Inwardly he rebels against the employer who makes him work in such surroundings.

THE FACTORY POWER STATION

In the construction of the factory buildings, special attention was given to light and ventilation. The walls are practically made of windows, steel construction allowing the brick work to be reduced to less than a fifth of the wall surface. Even the brick work below the window sills has been cut away, and low sashes have been substituted. This insures, in the remotest corner of every work room, light enough for the most delicate operations. Curtains on all windows temper this light. For all but the windows with a northern exposure, there is a second curtain of white material which keeps out the direct rays of the sun without sacrificing any of the light.

With the windows open in the summer, perfect ventilation is provided for. In winter, when the huge

EMPLOYEES' HOUSES OPPOSITE THE FACTORY



A REAR VIEW OF SOME OF THE HOUSES. MOON FLOWERS AND MORNING GLORIES HELP TO BEAUTIFY THEM

sashes are bolted down to keep out the cold, a system of ventilating fans changes the air in every office and work room four times every hour. Fresh air is drawn from the roofs, warmed, and driven through the supply mains to the various departments. It is admitted to the rooms through registers placed near the ceilings, while the foul air is drawn off from the floors by a corresponding series of exhaust tubes. The temperature of the rooms is kept standard in each building by an inspector who makes the rounds of all the departments every hour.

Absolute cleanliness is demanded in all the departments throughout the factory. All office and work rooms are swept each morning before their occupants begin work. Floors are scrubbed once a week. The factory windows are kept as speckless as those of the smartest office building. Eighty janitors are employed at this work of factory housekeeping, and they frequently work overtime to keep the twenty-three acres of floor space as clean as the management demands.

In line with this belief that surroundings influence workmen as well as poets, the whitewash sacred to factories has been banished entirely from the National Cash Register establishment. Instead, cool tones of green and brown are used on walls and pillars, while the ceilings are done in cream. Wherever interior partitions are needed, only enough wood is used to frame the glass of which they are made.

The first effort in welfare work made by the thousand or more manufacturers and merchants who have followed the lead of the National Cash Register has been the establishment of dining rooms for employees. At Dayton a separate building,—"Welfare Hall,"—had been erected to house this single feature of the company's work. It is 328 feet long, and 60 feet wide, and contains two great dining rooms,—that for the girls seating 600, while the men's room can be expanded to accommodate 900. The kitchens are in an adjoining building.

"Welfare Hall," though substantially built, is a temporary structure, and in time will be replaced by a huge permanent building with a lunch room for the company's 4000 workers, an auditorium seating 12,000, a gymnasium, and reading rooms.

Until June 5, of this year, the dining rooms for both men and women, with the factory kitchen, were in the office building. The growth of the business made it necessary to take the space used by the dining rooms for executive offices. To cut short the interruption of the noon-day luncheons, "Welfare Hall" was planned, erected, decorated and dedicated all within the space of three weeks. All the work, from the drawing of the plans to the making of the flags that fly over the new building, was done within the National Cash Register organization. It was characteristic of the company's methods that "Welfare Hall" was opened with a dinner to the carpenters, plumbers, painters, masons and electricians who erected it.

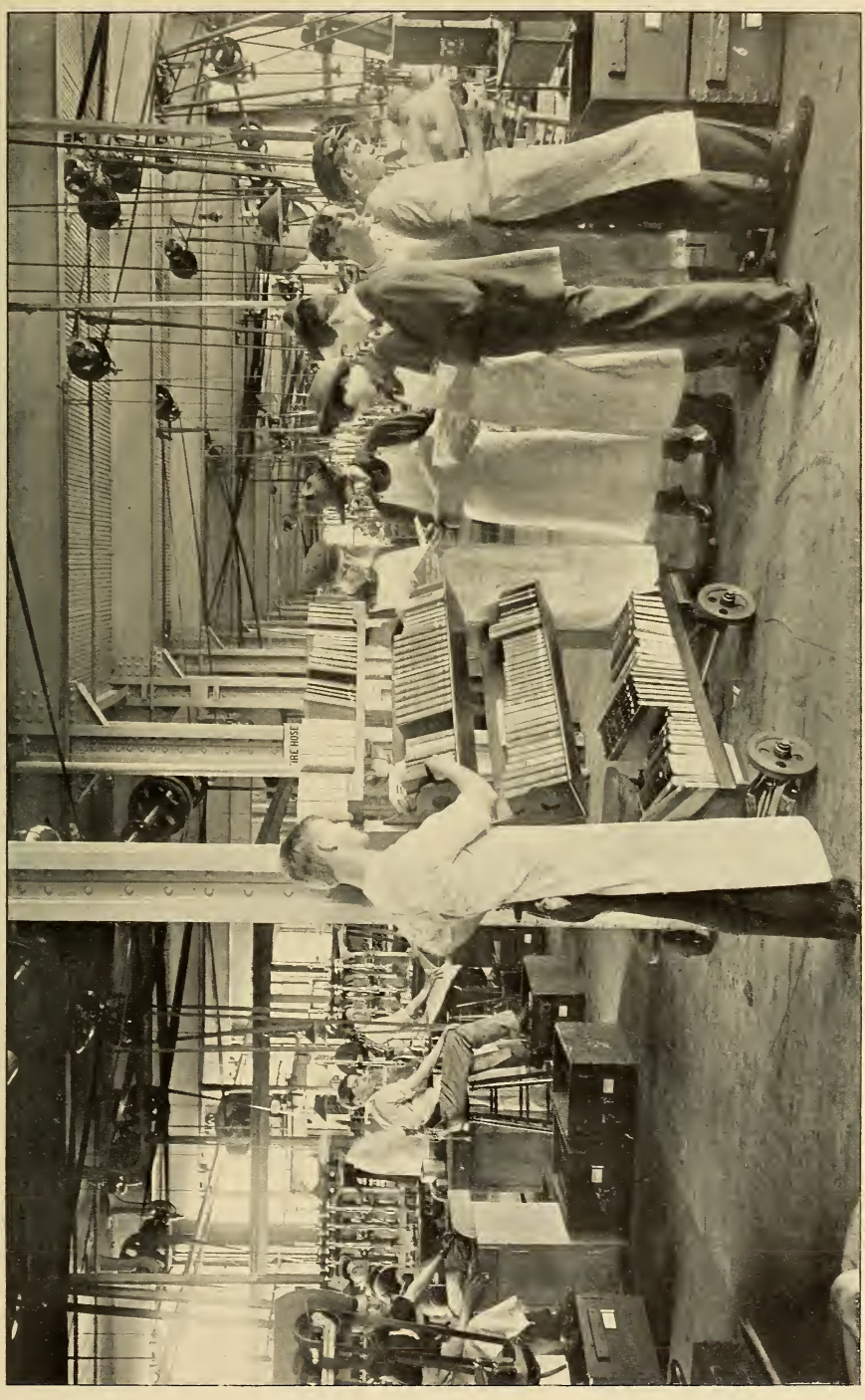
It is the company's conviction that the cost of maintaining "Welfare Hall" is more than made up by the increased efficiency of the men and women lunching there. Indigestion, due to luncheons eaten cold at work benches, or bolted at home during the short noon hour, is an item which cannot be figured on cost tickets, but it exists, nevertheless, in every factory.

The charge for these noon-day lunches is based on the flat cost of the raw materials, the company doing the cooking, and furnishing service free. The six hundred women who lunch at "Welfare Hall" pay twenty-five cents a week. Here are two sample menus from the women's dining room for Monday and Tuesday of the second week in July:—

MONDAY

Beef broth with rice.
Browned potatoes. New beets.
Shredded wheat biscuit. Bread and butter.
Coffee, milk or postum.

ONE OF THE CHEERFUL WORKROOMS. ATTENTION IS CALLED TO THE HIGH-BACK CHAIRS AND THE APRONS AND SLEEVELETS, ALL OF WHICH ARE FURNISHED FREE BY THE COMPANY



THE TRAVELING LIBRARY IN THE TOOL ROOM. TO MAKE THE FACTORY LIBRARY ACCESSIBLE TO ALL WORKMEN, BOOKS ARE DELIVERED TO THE DEPARTMENTS DURING THE NOON HOUR

IN THE WOMEN'S DINING ROOM IN WELFARE HALL LUNCHEON IS SERVED TO SIX HUNDRED WOMEN EMPLOYEES AT A CHARGE OF FIVE CENTS A MEAL

TUESDAY

Cold roast beef.
Mashed potatoes. Cold slaw.
Bread and butter. Cocoa or coffee.

In the men's dining room the charge is either seventy-five cents or one dollar a week, according to salary. The meals are substantial, as may be seen from the following menus for the same days as the women's menus just quoted:—

MONDAY

Roast beef with gravy.
Mashed potatoes. Cabinet pudding.
Boiled rice. Zwieback, bread, butter.
Shredded wheat biscuit. Coffee, milk, postum.

TUESDAY

Split pea soup.
Stuffed roast veal. Pineapples.
Browned potatoes. Zwieback, bread, butter
String beans. Coffee, milk, postum.

For the 210 department executives, factory foremen and assistants, the National Cash Register Officers' Club," a block from the factory, serves all the purposes of "Welfare Hall" with some added features. The head of the National Cash Register Department of Domestic Economy, formerly manager of the "oak room" at the St. Regis Hotel, New York, is the steward of the club, and the fare and service could hardly be bettered.

The long lunch hour of eighty minutes gives time for special and business talk over coffee and cigars. Scarcely a week passes that some noted visitor,—Cardinal Satolli, Prince Hohenlohe, Jacob A. Riis,—is not the guest of the club and makes a brief address to his hosts.

Matters of company policy are discussed at intervals, and the "teamwork," for which the National Cash Register organization is known among manufacturers, is largely due to the spirit developed about the big, round table of the club. So marked, indeed, has been the effect on the company's executives that in June of this year the club house was enlarged and the membership of the club doubled in order to bring the assistant foremen of the factory departments into the circle.

The noon-day lunches for employees is the first link in a remarkable system of welfare work which brings the company into touch with every member of the organization,

both at Dayton, and in the selling field. For instance, 120 shower-baths of the most modern sanitary construction have been fitted up in the 73 lavatories for men scattered throughout the factory. Two baths a week are allowed on the company's time in summer, and one in winter, with as many additional baths as any individual desires. Hot and cold water, bath towels and toilet accessories are furnished free of charge. For the women there are fourteen tub and shower baths.

Ten-minute recesses are given morning and afternoon in the office division, and in all departments employing women, and most of this time is given to regular exercises in physical development. One of the most successful teachers of the Sandow Institute, London, has been employed to conduct these classes, training the leaders at regular intervals. The benefits from these classes have been so marked that the work will be extended during the coming winter.

Perfectly appointed rest rooms are maintained near all the departments employing women, and two trained nurses are on duty at the factory during working hours to answer emergency calls. The factory hospital is a model of compact efficiency, including an operating room, a rest room, a dispensary, and a room for hydropathic treatments. A physician is always within call. In addition, the foreman and assistant foreman in every factory department have been taught the pinciples of "first aid," and an emergency case of remedies, with directions for using them, is kept in each department office.

THE N. C. R. OFFICERS' CLUB. TWO HUNDRED FACTORY AND OFFICE EXECUTIVES, WITH THEIR ASSISTANTS, TAKE LUNCHEON HERE TOGETHER EVERY WORKING DAY

During certain hours of the day an optician is on duty at the factory, and consultation and treatment may be had by employees without cost. Lectures on health are also given to the factory employees by authorities like Horace Fletcher, author of "the A. B. C. of our own Nutrition," and "Menti-Culture." Requiring all employees to pass a physical examination when they enter the factory, in order to protect the other workers,

A COOKING CLASS IN THE FACTORY KITCHEN. TWO-THIRDS OF THE WOMEN EMPLOYED IN THE FACTORY HAVE TAKEN A PRACTICAL COURSE IN THE BEST THINGS TO COOK AND HOW TO COOK THEM

FIVE MINUTES OF EACH OF THE MORNING AND AFTERNOON RECESSES IN THE DEPARTMENTS EMPLOYING WOMEN ARE DEVOTED TO CALISTHENICS

the National Cash Register spares no effort to keep them healthy and make their work safe and pleasant.

In a hundred minor details of factory management, the company's thought for its employees is shown. Elevator service for all men and women is one of these, the elevators starting ten minutes before work begins, and continuing ten minutes after the day is ended. High-backed chairs with foot rests are provided for all women employees. Clean aprons and sleevelets are supplied twice a week.

The 600 women at the factory quit work ten minutes before the men, and come an hour later in the morning to insure their having seats in the street cars. In the brass foundry special precautions are taken to prevent prostrations by heat. In the polishing rooms a vacuum system carries off the dust from the buffing wheels. When men are required to work overtime, substantial dinners are served to them in "Welfare Hall" at half past five o'clock.

To provide the clean towels, napkins, table cloths, aprons, etc., which enter into National Cash Register factory economy, a fully equipped steam laundry has been installed. It has twenty employees, and launders 35,000 pieces of linen every week. Contrary to custom, it is not in the basement, but on the fifth floor of the newest factory building, and is as free from steam and odours as the general managers' offices.

Looking after the physical welfare of the employees, the company has not neglected mental development. Regular courses of instruction are offered in English composition, salesmanship, cooking, sewing, embroidery, dancing, emergency nursing, both for men and women, Bible study stenography and the languages. Demand for instruction in any subject by employees is always met by provision of a teacher and a lecture room.

Progress and growth are almost mandatory on National Cash Regis-

A CLASS IN EMERGENCY NURSING RECEIVING INSTRUCTION

RETIRING ROOMS ARE MAINTAINED IN EACH OF THE DEPARTMENTS EMPLOYING WOMEN

ter employees. For instance, last winter and spring two courses in English composition were given on the company's time, in addition to the regular night class in English. One of these special classes met twice a week, the other once a week, each lecture ocupying an hour. Nearly two hundred employees attended, most of them being stenographers, correspondents and department secretaries.

Two hundred young women took the cooking course last winter. Three hundred followed it the year before. The first class in emergency nursing for women was begun last October with sixteen members. The second, organized in January, contained one hundred and fifty, and was handled in sections. Two courses for men in "first aid" were also given. It is nothing wonderful that the most popular classes of all were in dancing. Five hundred National Cash Register men and women attended one or the other of the two classes. For "commencement" the company gave the dancing classes an open-air cotillion which was the prettiest garden party ever held in Dayton.

Training schools for salesmen are also maintained by the National Cash Register Company in New York, Chicago, St. Louis and San Francisco. The normal courses in the art of selling cash registers cover six weeks, the students dividing their time between class-room exercises and actual work in the field. Of these schools it is enough to say that many of the leaders of the National Cash Register selling force are graduates of the last two years. Similar

THE FACTORY LIBRARY DURING THE MORNING RECESS. TWO THOUSAND VOLUMES, CURRENT MAGAZINES AND FORTY NEWSPAPERS ARE HERE AT THE DISPOSAL OF THE EMPLOYEES

IN THE FACTORY LAUNDRY THIRTY-FIVE THOUSAND PIECES OF LINEN, APRONS, SLEEVELETS FOR EMPLOYEES, TOWELS, TABLECLOTHS, NAPKINS, ETC., ARE LAUNDERED EVERY WEEK

schools are conducted at the factory for employees ambitious to enter the selling field. Post-graduate summer courses, lasting two weeks, are also provided for salesmen at the factory, and every member of the selling force takes this course at least once in two years. So firmly grafted on the National Cash Register organization is this educational idea that even the monthly meetings of the two hundred department executives is known as a session of the "Officers' School."

Supplementing the work of the schools for employees is the factory library on the first floor of the office building with its 2000 volumes on mechanics, engineering, history, literature and other subjects. Forty of the leading weekly and monthly magazines and the principal daily newspapers are on file.

The library is open to all of the office and factory employees, and to the residents of the neighbourhood. For the convenience of those in the factory, and to encourage reading, traveling libraries have also been instituted. Every noon, books on wheeled racks are trundled to the main entrances of the three main manufacturing buildings so that employees may make selections without leaving their work rooms. Books are issued for one week on payment of one cent. They may be renewed for an additional week if desired.

Travel as a means of education is another National Cash Register conviction. For years, delegations of its foremen and workmen have been sent to the chief cities and manufacturing centers of the country in order that they grow familiar with working conditions elsewhere and obtain ideas for improving the equipment and conditions at the National Cash Register factory.

The greatest of these "educational trips," as they have come to be known, was that made by 2200 National Cash Register employees to the World's Fair at St. Louis last summer. The company paid the traveling

THE WOMEN'S CENTURY CLUB HAS A MEMBERSHIP OF FIVE HUNDRED. IT PROVIDES A HOME FOR THOSE OF THE EMPLOYEES WHO HAVE NO KINSFOLK IN THE TOWN

expenses and admission fees of 200 department executives and their wives, and of 600 women employees. Half the fare to St. Louis was paid for 1400 additional employees. Six special trains, one entirely of Pullman cars, was required to transport the National Cash Register forces to St. Louis, where the Fair management set aside August 6 as "Welfare Work Day."

The World's Fair trips were under the direction of the Men's Welfare Work League and the Women's Century Club,—two associations which the employees have formed of their own accord to supplement and extend the company's welfare work. The Men's League rented three floors of a brick apartment hotel near the Fair Grounds and gave its members extremely low rates. It took a physician and a trained nurse to St. Louis to look after ailing members, established a bureau of information, and even secured admission concessions from the shows on "The Pike."

The Women's Century Club hired five big residences in a quiet quarter of the city and duplicated for its members the advantages offered by the Men's Welfare Work League.

Affiliated with the Ohio State and the National Federation of Women's Clubs, the Women's Century Club is making a most important experiment in providing a home for those of its members who have no kinsfolk in Dayton. A beautiful, colonial farm house, the old Patterson homestead, has been leased for ten years at a low rental, and the huge barn has been remodeled into an assembly hall and dormitory. Here club members find homes in the most delightful surroundings at lower cost than in the average boarding house. The cooperative home for working women is new enough to make the club's experiment well worth watching. The club publishes a quarterly magazine,—"Women's Welfare,"—with the idea of spreading the gospel of welfare work everywhere.

THE FACTORY COTILLION IN WHICH THE YOUNG MEN AND WOMEN,—MEMBERS OF THE FACTORY DANCING CLASSES,—PARTICIPATE

TRAINING CLASS FOR SALESMEN. OFFICE EMPLOYEES LEARNING HOW TO DEMONSTRATE AND SELL NATIONAL CASH REGISTERS PREPARATORY TO THEIR ENTRANCE INTO THE SELLING FIELD

THE COMPANY'S STORAGE HOUSE FOR BICYCLES AND AUTOMOBILES OF THOSE WHO RIDE TO AND FROM THEIR WORK

In its turn, the Men's Welfare Work League has taken over one of the two neighbourhood settlements supported by the company and is administering it with great success. Classes are conducted in sewing, embroidery, wood carving, basketry, water-colour work, physical development, and dancing for men and women as well as for children. Two military companies have been formed for the neighbourhood boys. A vacation school is maintained with 200 pupils, in which sports and games play a large part. Free public baths, with seven showers, have been fitted up and thrown open to the neighbourhood,—the first in Dayton.

Interest in the public schools and in the movement to secure parks for Dayton, and abolish grade crossings, are also part of the league's programme. A gymnasium and cooking school have been fitted up at the Patterson public school to show Dayton what can be done in this direc-

tion. The league publishes a weekly newspaper,—"The Bulletin," which has come to have great influence in local affairs. To promote athletics, the league supports a base ball team, which for years has won three out of four of its games with Ohio and Indiana colleges and amateur teams, and holds an annual track meet in September. The league's athletic field, a block from the factory, has a base ball "diamond," a foot ball "gridiron," a quarter-mile running track, six tennis courts, and an open-air gymnasium. A vacation play ground for children was also fitted up in June.

The most ambitious undertaking of the Men's Welfare League, however, was the co-operative vacation outing arranged for its members at Port Huron during the first two weeks of August. A city of one thousand tents was erected on Huronia Beach, with a careful eye to sanitation and the comfort of members. A dancing platform and the National Cash Register Band made evenings merry, and the league turned restaurant keeper for the two thousand who made the trip.

The kitchen and dining tents were in charge of the National Cash Register Department of Domestic Economy, and the most substantial and appetizing fare was served at a charge of ten cents a meal. The league made the trip in special trains to Detroit, and thence on a chartered steamer to Port Huron. The charge for transportation—a round trip of four hundred miles—and tent rent for ten days was kept down to $5.20. This is nothing less than a revelation of the economy of co-operative camps for vacation outings for working men and their families.

For all this welfare work, what does the National Cash Register Company get in return? Co-operation of men and managers for one thing. For another, a product so nearly perfect that the company sells 95 per cent. of the cash registers marketed in all parts of the world. And through its unique suggestion system,* practical returns are also secured which can be measured in direct money saving to the company.

Suggestions for the improvement of its machines and methods, for the decreasing of factory and office costs, are asked of all employees. Boxes for suggestions are scattered everywhere throughout the plant. For every suggestion adopted, a dollar is paid to the employee who offered it. These dollar prizes are awarded monthly. In addition, forty-nine quarterly prizes, amounting to $3000 annually, are awarded for the most valuable suggestions, separate prizes being provided for department executives and ordinary employees.

Through its suggestion system, the company is able to bring the brains of the workers to bear on its manufacturing and selling problems. In this way, too, it reaps the benefit of its educational work,—libraries, classes for employees, "educational trips," and the daily and monthly papers which it publishes for employees. So closely in touch are management and men brought that the company has been called a "5000-brain-power organization."

All this is in the abstract. To get down to concrete facts, the profit on the suggestion system for the current year, if the average of the first six months is maintained, will be nearly $30,000.

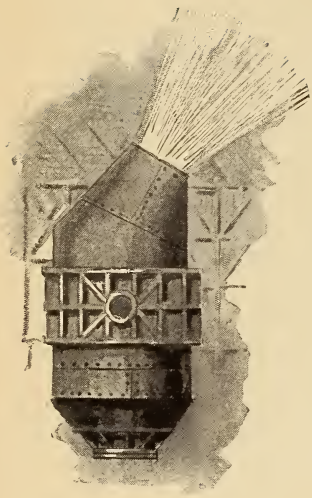
Through welfare work and the suggestion system, besides, National Cash Register men and women everywhere are working to solve society's greatest problem, and to realize President Patterson's ideal of capital and labour meeting on common ground where they may work together in harmony for their common good.

* It may be interesting in connection with this to refer to the article on "The Suggestion System," by H. F. J. Porter, printed in the July, 1905, number of this magazine.—The Editor.

FERRO ALLOYS

THEIR USES IN THE IRON INDUSTRY

By Auguste J. Rossi



ORDINARY carbon steel possesses certain properties, depending, amongst other things, on the amount of carbon it contains, and on the state in which this carbon is met with. The presence of another metal may modify these properties in one sense, for instance, by making the steel of a harder temper, and therefore better adapted for special applications, or it may impart to it valuable properties of resistance to shocks, or again cause it to be self or air-tempering, as it is called. However valuable for specific purposes these qualities may prove to be, it does not necessarily follow that the peculiar metal which has secured them is good in every case, as it may well be that these qualities have been obtained to the detriment of others inherent in the normal steel and requisite for many of its most usual applications.

These remarks will explain why the researches of metallurgists have covered the field of metals not before thought of, owing to the imperfect knowledge we had of some of their rare occurrences in nature, or the difficulty of obtaining them industrially. The influence on the properties of cast iron and steel of the best known metals, such as aluminium, chromium, nickel, and manganese, has been recognized for many years, and their use has become extensive, especially that of the last two mentioned.

As our knowledge of the rarer metals, or those hitherto less studied, even if abundantly found, has become more complete, and as it has become practicable to manufacture them industrially by special electric methods, owing to the development of the electric furnace, the attention of metallurgists has been drawn to them more and more, and to their possible uses. Thus tungsten, molybdenum, vanadium, uranium, and titanium have been more especially experimented with, and their special virtues have become known. Some, like vanadium, were found to impart to steel a greater ductility, toughness, and strength; others imparted greater hardness of temper, like tungsten and molybdenum; others still, like titanium, were found to act specifically as purifiers by eliminating from the iron detrimental constituents of which the action was not very well determined.

Robert A. Hadfield, of Sheffield, amongst others, has been one of the foremost to realize the importance of these alloy-steels, and in his presidential address to the Iron and Steel Institute this year, sounded the right note by calling attention to the immense service which these ferro-metals have already rendered to the iron industry in general for high-speed tools, and in military engineering, as also to those which may be expected from them in the future.

The writer does not intend here to examine into the special influence exerted by each one of the metals

mentioned above, but will confine himself to the consideration of one,—the last comer,—titanium, which he has particularly studied, and to which recent investigations have given special prominence. What the writer may have to say of the manufacture of this metal or its ferro combination in the electric furnace, applies equally well, in a general way, to that of any of the others mentioned; in fact, the same methods have been used for all. As a rule, the quantity of metal added as a seasoner to molten iron or steel is comparatively small, and as the cost of production of a ferro metal,—that is, of an alloy of a given metal with iron containing any high percentage of the metal desired,—is less than that of the metal itself, most frequently, or preferably, the addition of the ferro alloy is resorted to in order to introduce a given metal in the steel. It may be added that a ferro alloy, as a rule, is more fusible than the metal itself, and as such is more quickly and thoroughly incorporated in the finished product.

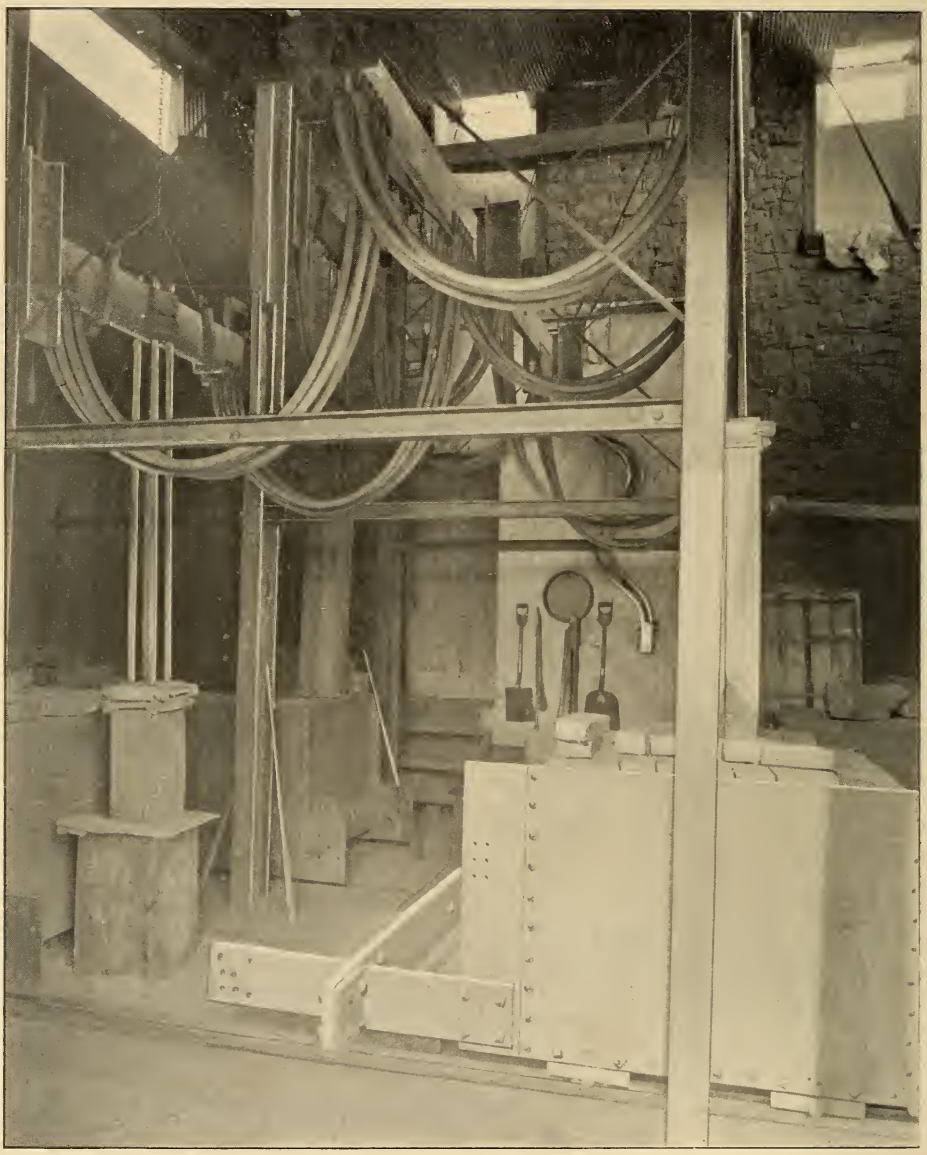
Some of these metals more lately resorted to in the iron industry occur but sparingly in nature as already mentioned, and are very expensive, and as Prof. H. M. Howe remarked at a recent meeting of the American Institute of Mining Engineers,—"We have to hope for the development of high-speed tools from elements which exist in great quantities rather than from these rarer metals, like vanadium, molybdenum, and tungsten, the supply of which is likely to be soon exhausted" * * * "is not to last more than a generation."

It may then be of interest to recall the possibilities of titanium, to the metallurgy of which the writer has devoted several years of study, and which, as stated in a recent article by Dr. Hans Goldschmidt, "had first an uphill task to become popular as a new candidate to favour, but is now beginning to be more regularly used (since about two years) by a number of steel works in Europe."

For the last ten years or so, the writer has called the attention of metallurgists to the beneficial influence of this metal on the properties of cast iron and steel, in different papers read before scientific societies, or articles which have appeared in technical publications. What can be said of it, is that its ores are found abundantly, and generally as ordinary iron ores occurring as titaniferous iron ores, containing from 10 per cent., or less, to 45 per cent, or more, of titanic oxide (titanic acid), associated with oxides of iron. They occur in many localities in mountain masses, and their cost is not any higher than that of iron ores free from titanium. Rutile itself (titanic oxide or acid) has been found in many places, and more lately in large deposits in a feldspathic rock formation in Virginia, from which, by an easy water concentration, it can be obtained 90 to 95 per cent. pure at a price which is but a fraction of that of the ores of the rarer metals, molybdenum, vanadium, tungsten, and uranium.

If titanium has been called or considered a rare element for the last ten years or so, it was not on account of its being found in small quantities in nature, but because until titanium or ferro-titanium could be obtained industrially by the ton in the electric furnace, or in still very important quantities by the thermic method of Dr. Goldschmidt, the metal was to all purposes a laboratory curiosity.

All metallic oxides may be said to be reduced by carbon to the metallic state; but while oxides of iron and manganese, for instance, and even to a great extent, oxides of chromium and silica (oxide of silicon) are thus reduced at the temperature prevailing in the blast furnace, yielding pig iron, ferro-manganese of 80 to 85 per cent. manganese, ferro-chromium of about 60 per cent. chromium, and ferro-silicon of 12 to 15 per cent. silicon, other oxides are not so reduced; or if so, and imperfectly, the metal reduced is not fusible in these



ELECTRIC FURNACE USED IN THE MANUFACTURE OF FERRO-TITANIUM. SEE PAGE 363

conditions. It is necessary in treating certain oxides, and amongst them titanic acid, to resort to such temperatures as can be secured only in an electric furnace.

Whenever titaniferous iron ores, that is, magnetites or other iron ores containing titanic oxide, have been smelted in a blast furnace, the pig iron has been found to contain either no titanium at all, or but a very few hundredths of one per cent.,—rarely a few tenths of one per cent. or thereabouts (reduced in such cases by other agencies than carbon); and in these cases it mattered nothing whether the ore smelted contained 1 per cent. of titanic oxide or less, or 45 per cent. of it, or more. The pig iron, however, possesses remarkable

toughness, and this fact suggested naturally the idea to secure better results and improvements in iron or steel, by adding to these products a titanium alloy or ferro-titanium, prepared electrically or in some other manner, and containing such a quantity of titanium as would allow the incorporation in the metal treated, of a more important amount of titanium,—any amount desired in fact, or at least as much as is found occasionally in the pig iron smelted in the blast furnace from titaniferous iron ores.

Whenever a metallic oxide is reduced by carbon, the product is likely to contain more or less of carbon, often as much as 5 to 8 per cent., or even more. Unimportant as this may be when cast iron is to be treated with it, for certain applications the presence of such carbon may prove objectionable, and either another method of reduction has to be resorted to, or special refining, involving extra expense, has to be carried on in order to remove as much as possible of this carbon excess.

What the writer is going to say about the electrical manufacture of ferro-titanium, either free from carbon or containing some of it, applies equally well to that of any other metals or ferro-metals reduced from their oxides, associated or not with oxides of iron. The electric furnace used by the writer at Niagara Falls was an arc furnace of the old Siemens furnace type of twenty-five years ago. It consisted essentially of a species of masonry of graphitic materials, incased in an iron shell connected at the bottom with one of the bus-bars supplying electric current.

In this masonry there was a central cavity of proper dimensions in which, by means of appropriate devices, a carbon electrode could be moved up and down, of a sufficient area to carry the current used, or formed of a bunch of smaller carbons or pencils connected together.

THE TRANSFORMER ROOM THE CURRENT IS STEPPED DOWN FROM 2200 VOLTS TO 20, 80 OR 100 VOLTS OR MORE

This constituted the cathode, the graphite crucible constituting the anode. This cathode was connected with the other bus-bar by means of flexible cables. The annexed illustrations of the furnace explain themselves. The carbon cathode is connected by means of copper rods (screwed in) with a cross bar of copper, which can slide vertically between two upright posts by means of properly insulated slide pieces, the movement being secured by chains connected to a rope which is wound up on the drum of a windlass driven by means of a worm and pinion. The current supplied was transformed from the 2200 volts of the primary to any voltage desired, from 20 to 80 or 100 volts or more, by a special transformer. There were four of such furnaces. They were 4 feet square, and about $3\frac{1}{2}$ feet high, and each was supplied with 200 H. P. of current. They were so disposed on rails that each one could be independently connected with a bus-bar common to all at the bottom of the iron shell.

The arc being started by lowering the carbon electrode in the cavity so as to almost touch the bottom of the furnace, the materials of the charge,—a mixture of powdered titaniferous iron ores and carbon in some form,—were put in the space provided for between the electrodes and the sides of the cavity. The furnaces could be closed at the top by means of suitable contrivances. The reduction proceeded at once, and when a sufficient time had elapsed, the ferro-metal obtained was tapped at a proper opening provided for in the graphite masonry and the charging was resumed, or this charging was kept up all the time or at certain intervals. Whatever slags had been formed during the operation were run out at another opening in the furnace. If, instead of titaniferous iron ores, chromic iron ores, or any other ores were charged, ferro-chromium or some other ferro-metal was obtained instead of ferro-titanium; and if rutile (titanic oxide) or the chromic oxides alone, free from oxides of iron were used, then instead of the ferro-alloys, the respective metals were cast.

The writer manufactured in this manner, ferro-titanium containing from 5 to 8 per cent. carbon, and from 10 to 35 per cent. titanium when using titaniferous iron ores. For higher alloys, above 35 per cent., there were added to the titaniferous iron ores in the charges the proper proportions of rutile (titanic oxide) in order to obtain a desired percentage, or rutile could be used alone. The writer has smelted in the same manner ferro-chromium of 68 per cent. to 78 per cent. chromium, containing 6 to 7 per cent. carbon. By refining the product with additions of metallic oxides without carbon, it was possible to eliminate the greatest part of the carbon; but in general, it is difficult to reduce the percentage to less than 1 or 2 per cent., and in order to obtain ferro-alloys or metals practically free from it, it may prove even more economical to use another method of reduction, which consists in substituting aluminium for carbon as a reducer, or a metal whose affinity for oxygen is greater at a high temperature than that of the metal to be reduced.

This reducing property of aluminium has been well known for the last fifty years or more, but merely as a laboratory experiment, because as utilized before, the reaction was so violent as to be explosive, projecting the materials out of the vessel in which the operation was conducted, thus excluding all ideas of its industrial applications. The aluminium, finely powdered, was intimately mixed with the powdered oxide to be reduced, and the mixture was introduced in a small crucible or vessel, which was heated externally. As soon as the temperature rose to a certain point, the aluminium combined with the oxygen of the oxide, yielding allumina, the heat disengaged by this reaction being suffi-

cient to bring the crucible and its contents to an intense white heat. The reduction itself was so rapid as to cause dangerous projections of the materials in a blazing state.

To Dr. Hans Goldschmidt belongs the credit of providing an ingenious method of making this reducing property of aluminium in powder form available for practical purposes, and for securing locally an intense heat, estimated at from 4500 to 5000 degrees F., which can be taken advantage of for soldering broken steel castings, and the like.

This "thermic method" has, of late, been frequently described. As applied to the production of ferro-metals or metals, it consists in charging in a proper vessel an intimate mixture of aluminium and the oxides to be reduced, both in the form of fine powder, starting the mass with a special primer made of powdered aluminium, and a very easily reduced oxide, such as peroxide of sodium or the like, starting the primer by means of a fuse, such as a ribbon of magnesium, like that used for flash light purposes for instance, or otherwise. The reaction sets in at once, proceeds by contiguity of mass without applying any external heat, and lasts but a very few minutes.

If the metal or ferro-metal obtained has to be kept liquid for casting, a fresh quantity of the primer has to be used to secure the necessary heat. The completeness of the reduction, and the quality of the product obtained depend on the thoroughness of the mixture of the materials used, and on their proper degree of fineness.

The writer has found that instead of using the more expensive powdered or finely comminuted aluminium, a quiet and complete reduction can be secured by charging in an electric furnace, such as the one just described for reductions by carbon, the oxides to be reduced in coarse grains in a bath of aluminium, made and kept liquid by the electric current. The reaction sets in at once. It can be moderated or stopped if necessary by raising the carbon electrode, or started again towards the end of the operation by lowering the cathode in order to keep the metal or alloy formed in a liquid state. The metal can then be cast, more aluminium charged in to form a new bath, and, by shovelling into the latter a fresh charge of oxide, the operation can be made continuous.

In this way the writer has been able to make ferro-titanium practically free from carbon, and containing from 10 to 75 per cent. and more of titanium. Applied to the reduction of other oxides he has also made in this way, in three-quarters of an hour, about 700 pounds of ferro-tungsten, containing from 76 to 78 per cent. of tungsten; and ferro-chromium containing 70 per cent. chromium. The cost of current does not amount to more than a fraction of one cent per pound of alloy produced.

If there is any objection to more than a small percentage of aluminium, or any, in the product, this can be readily removed by adding in the electric furnace at the end of the operation a fresh quantity of oxides above that calculated for a given bath of aluminium. In fact, the metal being in the liquid state, and so maintained by the current, it can be refined and freed from any other objectionable element, such as sulphur or phosphorous, as the case may be, by other suitable additions, as is practiced in the open-hearth furnace. In fact, the electric furnace can be considered as an open-hearth furnace in this case. It is clear also that if instead of titaniferous ores alone, there is charged in the bath of aluminium a mixture of such ores and tungsten ores, or of tungsten and chromic ores, or of any other oxides, any complex ferro-metal can be obtained, or if no iron oxide is present in the first materials, any alloys of desired metals may be obtained free from iron.

The writer would now mention the results obtained by treating cast iron

or steel with the ferro-titanium produced, (either free from, or containing, carbon), by any of the methods described above. For some reason, however, Dr. Goldschmidt, instead of using directly the metals or ferro-metals obtained by his thermo process, has introduced another method, which consists in adding to the metallic bath to be treated, not these metals or ferro-metals, but the materials necessary to obtain them, as a "thermit" as he calls it, that is, a mixture of the powdered aluminium and oxides in proper proportions for reduction contained in a sheet-iron box which is held by means of a handle in the molten mass of cast iron or steel. The reaction, started at the temperature of the bath, sets free the metal, ferro-titanium, for instance, which dissolves in the bath. It is not for us to discuss in this article the value of this method of treatment by "thermit" as securing the proper effect as compared to the direct addition of a ferro-titanium (a ferro-metal of a known composition) manufactured beforehand, nor to examine the relative economy of the use of aluminium in powder form, and of the aluminium in the form of scrap, ingots, etc., as a reducer. We give below results obtained by both processes with cast iron.

The writer's cast iron tests with ferro-titanium were made in crucibles, in the ladle, and in the cupola. Test bars were cast in each case for both tensile and transverse strength, and the average results are given in pounds per square inch. In all cases bars of the metal before treatment were cast for comparison, and, of course, bars of the same dimensions. For transverse strength tests the writer used bars one inch square, loaded at the center, with 12 inches between supports. For tensile tests, round bars $1\frac{1}{8}$ inches in diameter, and from 18 to 24 inches long were used. Some of the results obtained are given in the following table. The ferro-titanium used contained about 12 per cent. of titanium, and from 6 to 8 per cent. of carbon, and we added about one pound of it to every 100 pounds of cast iron. In all cases the ferro-metal was broken into small pieces before being added.

	TESTS.		Transverse Strength, Lbs. per Sq. Inch.	Increase, Per Cent.	Tensile Strength, Lbs. per Sq. Inch.	Increase, Per Cent.
Crucible....	Wm. Cramp & Sons Shipyard, Philadelphia, December, 1900.....	B	*2040	....	20372	....
	May, 1901 (official report).....	A	*2473	+23	26409	+29½
Ladle.....	Car Wheel Works, Pittsburg.....	B	2200	....	22100	....
	December 13, 1900.....	A	2710	+23	27300	+24
Cupola.....	December, 1902, Philadelphia Iron Works.....	B	2400	....	23900	....
		A	2950	+23	30500	+28
	Western Pennsylvania Wheel Mixture, 1902–03.....	B	2860	....	28000	....
		A	3350	+17	33900	+21
Thermit.... (Note.)	Dr. Hans Goldschmidt.....	B	3350	....	17949	....
	Thermit Method.....	A	3350	+17	19014	+ 6
	I Bars 1.181 in. x 1.182 in. x 39 in. II.....	B		....	17878	....
	II Bars 1.576 in. diam. x 31.50 in.....	A		....	20689	+15

* B refers to metal before treatment; A to the same after treatment.

In carrying out these experiments with steel, the writer added from 1 to $1\frac{1}{2}$ per cent. of ferro-titanium containing about 25 per cent. titanium or less, and practically free from carbon, made by the aluminium bath method. It may be of interest here to state that these ferro-titaniums are so much the lighter as they are higher in titanium (of which the specific gravity is only 4.84). The higher they are in titanium, the less fusible also do they become, and there does not appear to be any advantage in using alloys above 25 per cent.

The writer will briefly recall now the observations made as to the results of such additions in the several papers published by him for the last five years or so on these subjects. In these he finds his own statements

fully corroborated by those made by others since, based upon experiments conducted independently. In both cast iron and steel there are found occluded gases, oxygen, and nitrogen especially, the presence of which has been known for years as well as the influence they may have on the homogeneity of the metal, though for one of them, the nitrogen, not fully realized to its full extent until more recently.

In the writer's papers referring to these questions, he has said in part:—

"The addition of ferro-titanium to cast iron shows an increase of from 20 to 25 per cent. in the transverse strength, and from 20 to 30 per cent. or more in the tensile strength, according to the nature of the pig iron treated. Titanium increases the elasticity of steel as shown by the great reduction of area and elongation observed in tests with high-carbon steels. (1901.)

"It acts in removing the occluded gases such as nitrogen, which prevent the intimate contact of the crystals so necessary for strength. (1901.) Steel thus treated with ferro-titanium, and containing 0.10 titanium, or less, and 1.227 carbon, presented a very fine silky structure very homogeneous, and was quite free from blow holes. (1902.) * * * The action of titanium appears to be at least one of purification by removing the occluded gases, such as oxygen and nitrogen, especially the latter. In this manner blow holes may be avoided in the cast metal or ingots. (1902.) * * * We found that foundry iron was thus freed from blow holes, the metal was dense, close-grained, both the transverse and tensile strength showing considerable increase ("Iron Age," 1903).

In our experiments with steel we have found that very small quantities of titanium, as little even as 0.10 per cent. or less, give a greater density and close-grained texture to the metal, imparting remarkable tenacity, thus counteracting the fragility of certain steels." (1903.)

In short, independently of what its influence might be if introduced in molten iron or steel in larger important quantities, small additions of it seem to act as a purifier by removing detrimental elements. The writer's own observations have been entirely corroborated by eminent metallurgists. This property of titanium, once established beyond cavil, would prove of great importance, since at a minimum cost (as compared to other additions) the iron could be improved in its physical structure and consequent properties. Titanium burns in nitrogen with incandescence like iron in oxygen.

Metcalf, in his "Manual of Steel," several years ago called attention to the possibilities of using titanium to remove this gas from steel. He went further. At his instigation, Prof. Langley made analyses of crucible, open-hearth, and converter steels of practically the same composition, so far as silicon, carbon, manganese, phosphorous, and sulphur are concerned, and found the percentage of nitrogen diminishing from the first-named steel (crucible) to the last (converter),—a result sufficiently explained by the modus operandi followed in the manufacture of these different products; and still, as is well known, crucible steel is far superior to open-hearth steel, which is, in its turn, far superior to converter steel. The detrimental action of nitrogen seems to be manifest.

Quite lately (May 27, 1905), at a meeting of the French and Belgian group of the International Association for Methods of Testing Materials, Mr. Braune, a Swedish metallurgist, assistant in the laboratory of Mr. LeChatelier, read a paper on this same subject, the paramount importance of which was recognized at this meeting. Mr. Braune showed in a most scientific and precise manner, and as a result of both analysis and micrographic examination, that the fragility of certain steels of normal composition,—fragility not very well

explained before,—could be traced directly to the presence in the iron of nitrogen as iron nitride. The addition of such elements as could eliminate this nitrogen naturally suggested itself as a remedy, and in view of the beneficial influence of titanium in cast iron and steel, attention was called to this metal as a well indicated purifier.

Dr. R. Moldenke, secretary of the American Foundrymen's Association, in a paper on the physics of cast iron, said lately:—"On another hand, the use of titanium alloys is to be commended because the titanium reacts directly with any oxygen and nitrogen present in solutions, and, as a consequence, a purification takes place which cannot be overvalued. Increasing the strength of cast iron 20 per cent. without remaining behind as an integral part of the metal, seems to be the function of this new candidate for foundry favours."

Dr. C. F. Weber, in an article in "The Iron Age," said:—"The titanium introduced as an alloy at once combines with the gaseous nitrogen present in the molten metal, forming a stable nitride, which prevents the formation of blow holes, and thus produces solid ingots and castings. * * * The metal being free from free oxides and slags is more liquid and not pasty. All these details are proven facts,—they are the results of actual work done in the laboratory, the foundry, and the steel mill, complete records of which are extant for references." He says further:—"This very effective and simple cleaning of molten iron and steel from their contained impurities, as described above, makes a gray cast iron of quality very near that of soft steel. It makes a steel of a quality nearly equal to open-hearth, and open-hearth nearly equal to crucible steel, which is itself improved in every way."

Mr. C. V. Slocum, late president of the Keystone Car Wheel Company, of Pittsburgh, in a paper read before the Railway Club of that city (1903), said, after mentioning the writer's work in this line:—

"Our own experiments with the metal demonstrate that titanium in iron gives greater density to the metal, surprisingly increases transverse strength and gives a harder chill and wearing quality in the wheel * * * strengthening all parts of the wheel, including the plates."

Dr. Hans Goldschmidt has said:—"It is remarkable that very low percentage of titanium (below 0.10 of 1 per cent.) may produce remarkable changes," quoting as a proof experiments made in Rhenish Westphalia with thermit of which results are given in the table on page 366. He calls the attention to the differences of strength observed for practically no difference in the composition of the materials before and after treatment, and adds:—"An addition of titanium to steel, which contains about 0.80 per cent. to 1.20 per cent. carbon, scarcely increases the hardness of the steel, but it raises its elasticity, and is, therefore, advantageous for steels which are subjected to much percussion, and which it is important to render as little brittle as possible. It is also used for cutting tool steels."

Similar statements can be found in many articles in "Stahl und Eisen."

What the writer desired to show by the preceding quotations is that in claiming for ferro-titanium, as he did at the beginning, the favour or consideration it seemed to be likely now to secure, basing such claims on the results of the tests which he himself carried on, or on those made under his supervision in foundries and steel works with the ferro-titanium manufactured by him in the electric furnace for the last five years or more, he finds endorsement now by well-known metallurgists on both sides of the Atlantic.

If such metals as tungsten, molybdenum, and vanadium, fail us, as Prof. Howe states will be the case in the near future, we may find in this

new candidate for favour the means of securing valuable qualities in cast iron and steel, and that, at a very small cost, the ores of titanium being, as already mentioned, very abundant almost everywhere, and available at as low a cost as those of iron, and a very small addition of titanium being sufficient for the purpose.

To the interested reader the following references to some of the literature of the subject may prove welcome:—

Titanium in Blast Furnaces. Journal Am. Chemical Society. Vol. XII, No. 4, April, 1890, page 91.

Titaniferous Ores in Blast Furnaces, 1893, Am. Inst. Min. Engrs. Vol. XXI, p. 832.

Smelting Titaniferous Ores. "The Iron Age," Feb. 6 and 20, 1896.

Influence of Titanium on the Properties of Cast Iron and Steel. Vol. XXII, Transactions of the Am. Society of Mechanical Engrs., Milwaukee Meeting, May, 1901.

Titanium in Cast Iron. Vol. X. American Foundrymen's Association.

Metallurgy of Titanium. Am. Institute of Min. Engrs. Vol. XXXIII, p. 179. Philadelphia and New York Meetings, Feb. and May, 1902. Prepared for the Journal of the Franklin Institute. (Joint meeting.)

A Brief Study of the Ferro-Metals and their Electrical Manufacture. "The Iron Age," Nov. 12, 1903.

Mineral Industries of the United States, Vol. X (1901) Titanium and its Alloys, page 715.

Mineral Industries of the United States, Vol. XI (1903) Progress in the Manufacture and Use of Titanium and Similar Alloys, page 693.

On the Manufacture of Ferro-Alloys in General and Ferro-Titanium in Particular in the Electric Furnace. "Electrochemical and Metallurgical Industry, November, 1903.

On the Manufacture of Ferro-Titanium and other Alloys Electrically. Report of the Fifth International Congress of Applied Chemistry. Berlin, 1903.

HAULING OIL WELL SUPPLIES

THE LATEST AMERICAN PETROLEUM DISCOVERIES

By Day Allen Willey

THE discovery of a grade of petroleum suitable for fuel and other purposes in the territory of the United States west of the Mississippi River, is of momentous importance, since there is no longer doubt that the deposits are of great magnitude and cover a wide area of territory. While many of the naturally-flowing wells in the older fields of the West are now being pumped, the output from each district during the past year verifies the statement that the western and southwestern States are producing more oil than even the Appalachian and Lima-Indiana territory which includes Pennsylvania, Ohio, Indiana, Kentucky, Tennessee and West Virginia.

It is a fact that in 1904 the States of Texas, Louisiana, California, Colorado, Wyoming, Kansas, and Indian and Oklahoma Territories contributed no less than 63,000,000 barrels. This is greater by nearly 20,000,000 barrels than the record of the same section for 1903. The total from the Eastern oil field did not exceed 55,000,000 barrels, according to the most reliable authorities.

The great expansion of oil production in the West and Southwest can be appreciated by referring to the year 1898. During this year the States of Pennsylvania, West Virginia, Ohio and Indiana furnished actually 94 per cent. of the output. Consequently in less than ten years the West and Southwest have risen from an insignificant factor in the industry, until their output is now many times greater than during 1898. Since 1903 the expansion of the industry has likewise been remarkable in its proportions, for the States west of the Mississippi contributed but 45 per cent. of the entire quantity during that period. Compared with Russia, the United States' petroleum product exceeds the combined out-

EXCAVATING FOR A HALF A MILLION BARREL RESERVOIR

A FLOWING OIL WELL IN CALIFORNIA

put of the Baku and other fields of the Russian Empire, to the extent of fully 40,000,000 barrels.

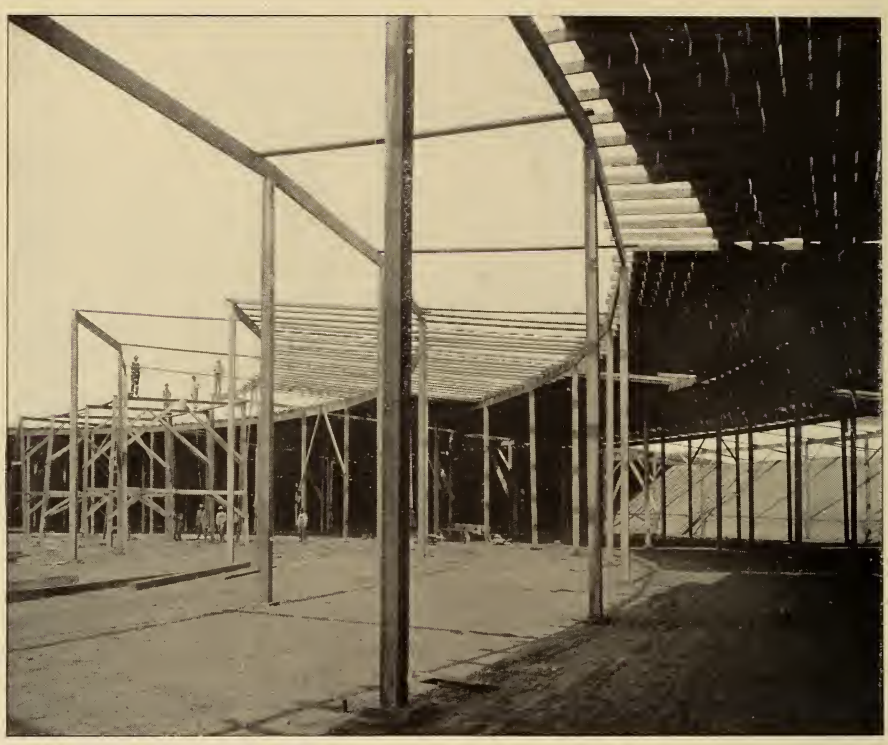
The area of oil-bearing territory beyond the Mississippi is so extensive that one may see derricks nearly spanning this section of America from East to West, but California and Texas are by far the greatest producers, although the quantity comprised in the Kansas field is so abundant that its quotum increased from 1,000,000 barrels in 1903, to 6,000,000 in 1904, and bids fair to reach 10,000,000 barrels during the year of 1905. The importance of California as a petroleum producer, referred to in CASSIER'S MAGAZINE for December, 1901, in an article describing the status of its development in 1901, was not exaggerated, as this State is yielding fully 25,000,000 barrels yearly. Its present production is estimated to exceed that of Ohio, which ranks second by 20 per cent.

As already intimated, the development of the several fields of the West and Southwest which resulted in their becoming such an important factor in petroleum production, dates back but ten years. The oil era on the Pacific Coast may be said to have begun about 1895, and in 1898 only a little over 2,000,000 barrels represented California's entire output. The "coming in" of the Lucas "gusher" marked the beginning of the activity in Texas. It is somewhat singular that the Lucas was among the first wells, as well as the greatest in the southeast Texas field, but the news of the "strike" spread with such rapidity that other prospectors who had also begun operations redoubled their efforts, and fortune-seekers flocked to this portion of the United States from all parts of America.

Land in the vicinity of the gusher, which before the discovery had sold for $40 an acre, was divided into lots, and in some instances disposed of for $40,000 an acre. Probably the most notable increase in the value of real estate was in a portion of what is now known as the Spindle Top district, where a tract which had been valued at $8 an acre was sold at $35,000 per acre. Within two months after the Lucas well began producing, the records of Texas show that no less than four hundred companies, claiming to have a capital of $175,000,000, had been organized to bore for oil, to sell land, to build refineries and pipe lines, or to deal in oil machinery. Oil began issuing from the Lucas well on January 10, 1901. Within thirty days seven more wells in the same district had begun producing at an estimated rate of from 10,000 to 25,000 barrels each, daily.

Beaumont became the metropolis of the field, increasing its population from 10,000 to 30,000 in three months, yet in eighteen months from the time of the first discovery the output had diminished to such an extent in the Beaumont district that pumping machinery had been installed at nearly every boring, while 750 derricks planted over "dry holes" had been abandoned. In July, 1902, records of the pipe-line companies, the railroad companies, and other authorities equally as reliable, showed that the aggregate daily production of the Beaumont field was but twice that of the single well which had caused an influx of people and capital into eastern Texas. It was calculated at that time that about 150,000 barrels were being secured, principally by pumping, every twenty-four hours. This was all the operators had to show for an investment of no less than $10,000,000, of which over $1,000,000 had been expended in borings which were valueless, $1,750,000 in producing wells, and the balance of the outlay for pipe lines, reservoirs, purchase of land, and the construction of five oil refineries.

At this point reference might be made in passing to the enormous quantities of oil which were wasted just after the discovery of the "gushers," for the reason that the prospectors were almost wholly unprepared



BUILDING ONE OF THE GREAT EARTHEN RESERVOIRS

to husband the supply. In fact, the waste was criminal in its proportions, as some of the more reckless operators allowed the wells to throw their contents into the air by the pressure of natural gas in order to sell the land about them at fabulous prices. This custom only ceased after a stringent law had been passed by the State Legislature prohibiting it. For nearly a week after it was "brought in," however, the Lucas well was entirely beyond control, and it is estimated that from this opening alone fully four hundred thousand barrels spread over the ground, filling the hollows for hundreds of feet around and actually forming creeks of oil which extended several miles before its force could be checked.

The enormous flow of oil in itself caused many to believe that the deposit underlying the Spindle Top district had given out and led to the abandonment of this district temporarily, but the resumption of operations proved that the supply was by no means exhausted, and that the failure of the gushers had been due principally to the exhaustion of the gas confined with the petroleum deposits, which in escaping had forced the oil to the surface.

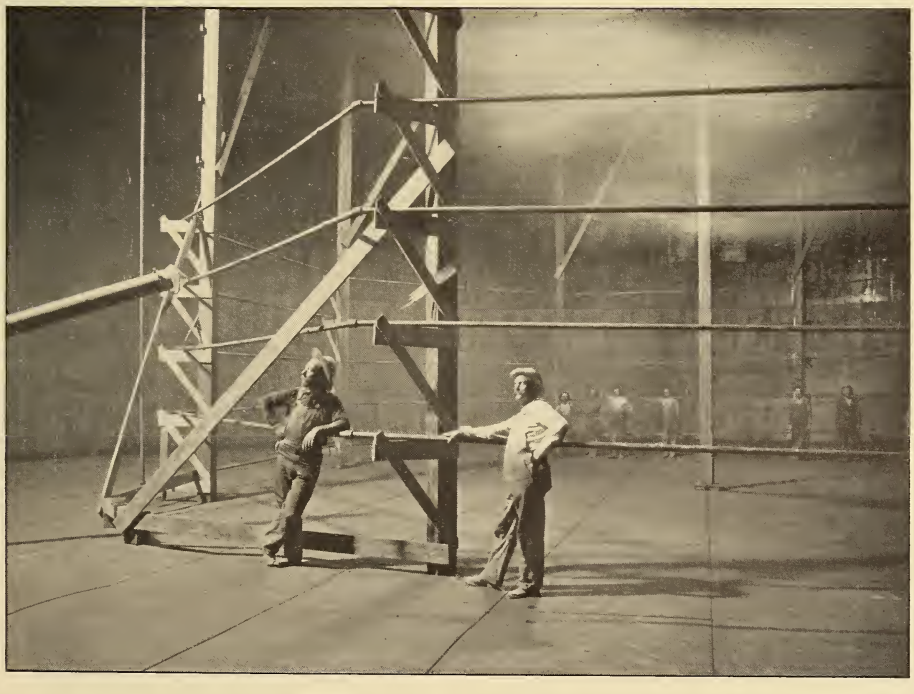
The temporary failure of Spindle Top has been an incentive to the development of four other fields, also in southeastern Texas, making five groups of operations from which the present output is fully 20,000,000 barrels yearly. The last field, and one of the most extensive—the Humble—did not begin yielding in commercial quantities until 1905. That this activity is confined only to a small part of the Southwestern deposits is proved by the operations in the vicinity of Jennings, Louisiana, where a considerable quantity is being secured.

This oil-bearing territory of the

Southwest has been termed the "Gulf Coast Oil Fields." Geologists who have thoroughly examined it are of the opinion that it extends from a point about 150 miles west of New Orleans, in Louisiana, to a distance of fully 200 miles. It is parallel with the Gulf of Mexico, and varies considerably in width. Although but a comparatively small portion of the Gulf Coast field has been tested by the well-borer, if the area which thus far has not been examined produces in the same proportion as those which have been developed, there is reason to believe that the supply from the entire field is so large that in a few years it will become one of the greatest petroleum-producing sections on the globe, not excluding the Baku fields, or those of Pennsylvania, Ohio or West Virginia.

That there are deposits of petroleum beneath one another in the Southwest is proved by the experience of the well diggers. At Beaumont, oil was reached at depths ranging from about 900 to 1100 feet. The larger wells near Jennings were struck at a depth of 1800 feet, while at Batson's Prairie, Texas, the wells range from 750 to 1200 feet in depth. Oil is found at Sour Lake and Saratoga, also in Texas, at about the same depths as at Beaumont.

The quantity of oil issuing from the first wells that "came in" on Spindle Top, caught the promoters unawares. The storage capacity provided was totally inadequate, and in some of the wells the pressure was so great that it could not be controlled by the valves. Thus, much of the product was wasted in the earlier stages of the industry. Realizing the necessity of larger reservoirs, excavations were made in the prairie, advantage being taken of natural depressions in the surface. These "earth tanks" as they were termed, probably suggested the use of the immense reservoirs which have succeeded them to a great extent in Texas and California. In their for-

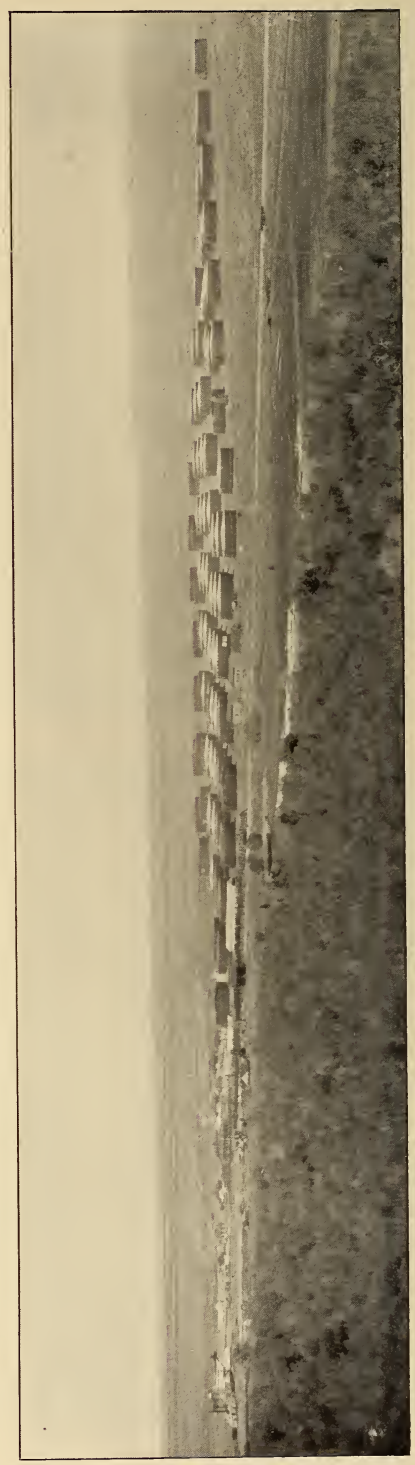


THE INTERIOR OF ONE OF THE GREAT TANKS,—LARGE ENOUGH TO SEAT A THOUSAND PEOPLE

mation the builders avail themselves of the topography of the country, and any natural rise of ground is utilized as a part of the wall, but an excavation from ten to fifteen feet in depth may be made with plows and scrapers.

The reservoir usually is circular in form, the walls being composed mainly of the earth taken out in making the excavation. The interior, however, is covered with a lining, sometimes of wooden planking, each plank being dovetailed or tightly joined to the adjacent ones. A more durable structure is lined with concrete. In fact it is a great shell of the material, as the bottom is also covered with it, openings only being provided for intake and discharge pipes. The top of the reservoir is covered over with wood, tin, sheet iron or specially prepared roofing material supported on a timber framework resting on the bottom or floor. The covering is not only essential to keep the oil free from dust and other impurities, but to protect it from rainfall, while during periods of high temperature there is danger of ignition from direct exposure of the liquid to the sun's rays. Consequently, some such covering as asbestos is desirable, and this material is frequently utilized.

To the capacity of these receptacles is due in a great measure the extent of the western and southwestern production, for this method of storage is so much more economical than the metal or wooden tank that it is utilized far more than any other form. Many of the reservoirs are erected adjacent to the wells which they are to serve, the discharge pipe of each well being connected with them. As some of the reservoirs in the Bakersfield district can hold no less than 500,000 barrels, a single one will suffice for an extensive series of wells. The smaller tank is also considerably utilized, being constructed both of wood and metal. In the Sour Lake field in Texas, cypress is employed for this



VIEW OF THE BAKERSFIELD DISTRICT, THE CENTRE OF OIL PRODUCTION IN CALIFORNIA, SHOWING STORAGE TANKS AND RESERVOIRS. IN THE FOREGROUND ARE 85 STEEL TANKS HAVING A CAPACITY OF 35,000 BARRELS EACH. TO THE LEFT IN THE DISTANCE CAN BE SEEN ABOUT 29 COVERED RESERVOIRS, NEARLY ALL COMPLETED, WITH A CAPACITY OF ABOUT 500,000 BARRELS EACH

purpose, some of the single vats holding 25,000 barrels. The iron tank is of the usual design seen in the eastern territory,—cylindrical in shape. It is generally connected to a series of others by overhead or buried conduits.

Referring again to the open reservoirs hastily excavated in the early days of the Texas development, so abundant was the flow of oil that in some instances it was carried to these receptacles by means of ditches or trenches cut in the prairie, to be stored like so much water. Despite the large amount of waste in thus conveying it, and the seepage through the earth banks of the reservoir, some reservoirs covering several acres in area were thus filled. Profiting by the experience of the operators at Spindle Top, the opening of the Sour Lake, Batson Prairie and other fields in Texas was attended by more economical methods. Covered reservoirs were erected in advance to store the output. When doubt was removed as to the extent of the output, pipe lines were laid from wells to reservoirs connecting with other conduits to Beaumont, Port Arthur and the principal shipping points. If the well borers struck the oil-bearing sand before storage facilities had been provided, the well was capped until its product could be cared for. In short, the development of the industry west of the Mississippi recently has been marked by careful and conservative methods.

Advantage has also been taken of the abundance of liquid fuel to use it in connection with the boring and pumping outfits where steam power is directly applied, or where the electric current is utilized. The use of the electric motor is becoming more and more customary, especially in California. In the Kern River valley a single plant may operate from 12 to 20 pumps, each having its individual motor, taking current by overhead wiring or cable from the central power station.

While we classify the oils from Texas, Kansas, California and the other western fields as petroleum, it differs widely in consistency from the petroleum of the older fields in the East. An analysis of the oil secured from Western Pennsylvania averages from 8 per cent. to 10 per cent. of naphtha, 5 per cent. to 9 per cent. of residuum, with but 5 per cent. of waste. A hundred gallons yield between 70 gallons and 80 gallons of refined oil, the average quantity of standard grade illuminating oil being 76 gallons. It is so volatile that when refined it gives eight different grades of naphtha, besides kerosene, while from the residuum are distilled several varieties of lubricant.

The petroleum from the trans-Mississippi wells is viscous in its crude form, and yields but a small quantity of illuminating oil, even by double distillation. It comes under the oils with an asphalt base, and consequently is suited for a variety of purposes for which the product of the Appalachian field would be unavailable. Perhaps its greatest value lies in the fact that its composition permits it to be utilized as fuel without refining, or in its crude state, and the bulk of it is consumed in this form. Fortunately for the West and Southwest, such an abundance of liquid fuel has been provided, since as yet a comparatively small tonnage of coal is mined west of the Mississippi.

Naturally, the attention of the transportation companies and large manufacturers was attached to the apparently abundant supply of oil in the Beaumont field, and taking advantage of the low prices at which the operators were forced to sell the product, they experimented with its use on an elaborate scale. Nearly all of the railroad companies equipped some of their locomotives with oil-burning apparatus and compared the results attained with those from the soft coal which was used as engine fuel. The outcome of these experiments proved that from three and a half to three and seven-tenth barrels of the ordinary Texas petroleum will

PUMPING OIL FROM THE CALIFORNIA DESERT

evaporate as much water as a ton of the ordinary bituminous coal used in the Southwest, and that at a cost of from fifty to sixty cents a barrel the oil is fully 25 per cent. cheaper than the coal, considering the cost of its transportation from the nearest mines. But contracts were made to supply the oil in quantities as low as twenty-five and thirty cents per barrel, so that the transportation companies in many instances have probably reduced their fuel bills fully 50 per cent. by the substitution of the liquid. By its use the services of the firemen can be dispensed with in many instances, as the engineer can regulate the supply by merely the pressure of the feed-valve, while a far larger quantity of the fuel can be carried in the tender than an equal amount of solid heat units, by converting the space used for coal into an oil tank.

These advantages have more than made up the expense of equipping the engines with oil-burners and tanks, the cost of which averages about $150 to a locomotive. The general manager of the Southern Pacific Railway has announced that all of the locomotives of that road are to be converted into oil-burners. This decision was reached after a trial made on the western division with thirty-nine engines. They consumed 12,000 barrels of oil at a cost of $3600 in train service, which it is estimated would have required 4000 tons of coal at a cost of $20,000 at the prices paid for this fuel on the Pacific Coast. This company has no less than 1400 locomotives, so that its requirements alone would take a very large quantity from the southwestern field; but the Atchison, Topeka & Santa Fe Company has about two hundred locomotives using oil, and will utilize it on additional engines during the next year, as will also the Missouri, Kansas & Texas, the Missouri Pacific, and other companies having railways in this section of the country.

Experiments made in sugar refineries as well as irrigation pumping

plants, rice mills, and other industries, indicate that oil at 50 cents per barrel is more economical than soft coal, and the sale of oil-burning machinery has become so extensive in Louisiana and Texas that this section is now one of the principal markets of the world for such equipment. Incidentally, it might be said that locomotives have been built purposely for the burning of liquid fuel, and on these the services of the fireman are dispensed with. They are in operation in California, and have given entire satisfaction. It may be added at this point that the number of heat units of the crude petroleum from California is as great to a given quantity as in the Texas or Kansas varieties. Therefore this field is available for the consumption on the Pacific Coast.

The oil is generally sprayed into the fire-box by a steam jet. The combustion is almost perfect, and waste of fuel so noticeable where wood or coal is used is reduced to a minimum. For the purpose of convenience, however, the "briquette," in which the petroleum is held as a solid, is finding favour in the West.

By mixing the oil in its crude state with certain chemicals, the compound is converted into a mass, which, when subjected to a pressure ranging from 300 to 1000 pounds to the square inch, becomes a solid substance, and can be handled like coal or wood. Tests which have been made with this compound show that a ton of it contains as many heat units as two tons of high-grade bituminous coal, such as the Welsh or Pocahontas varieties.

Advantage has also been taken of the heavy asphaltic base of the California oil to employ it in making highways where it is actually substituted for stone in giving a hard surface, and in forming a roadbed which will withstand the pressure of heavy loads. In this process, the first step is to plow the surface to a depth of a foot or more, using plows drawn by six or eight horses. With a deep sub-soil plow the earth is cut into clods, so that the whole road looks like a newly-plowed field in the spring. Next, labourers go over the road to break the clods in pieces. If the road has been oiled before, these clods are sometimes so hard

ASPHALTUM READY FOR SHIPMENT

that a sharp blow with a pick is required to break them. If the road has never been thus treated with oil, it is sometimes possible to dispense with the hand labour and use ordinary clod-crushers or rollers to pulverize the soil. A spike-toothed harrow breaks the clods into smaller pieces, and frequently two or three harrowings are required, alternating with the roller.

Heavy iron rollers drawn by four horses are used to crush the particles into smaller pieces, and after that the grader is employed to give a proper slope to the sides to shed water. The oil is not applied until the soil ten or twelve inches deep has been completely pulverized, graded, and rolled so that to the eye the road appears almost perfect. Then the oil is sprinkled over it to bind together the minute particles. The oil is applied heated to a temperature of 175 to 300 degrees F. It is carried in huge sprinkling tanks from the heating plant to the roads, and from 120 to 300 barrels are distributed over each mile of road.

After the oil is applied, a second sprinkling a few weeks later is sometimes made to insure perfect binding of the sand and dust. Then a top surface of coarse sand or gravel is applied to absorb any loose oil on top, and also to protect vehicles from coming in contact with the oil. In spite of the heavy wind storms prevailing in the West, no dust is blown from these oil-treated roads, and one may ride over them in the face of a heavy wind with as much comfort as if the road were recently sprinkled by an April shower. This is the finishing part, and if all of the work has been thoroughly done, a year may elapse before the highway requires any repairs. Over 1000 miles of California roads are thus composed.

The few refineries thus far erected on the Pacific Coast for treating the product of the California wells, obtain so small a percentage of illuminating oil that the principal purpose of refining the crude petroleum is to obtain what would be called the minor products in the East. These include gas distillate, asphaltum and grades of the heavier lubricating oils which are frequently combined with other substances for the manufacture of lubricating compounds. A small percentage of naphtha is the result of redistillation.

The petroleum from Eastern Texas contains such a percentage of sulphur that to obtain illuminating and lubricating oils it is treated a second time in stills containing copper oxide. Only by this method of redistilling has it been possible to free it from the sulphur.

RAIL MOTOR CARS IN GREAT BRITAIN

PART I.—GENERAL CLASSIFICATION.—SOME STEAM CAR EXAMPLES

By J. F. Gairns

FROM an economic point of view, the extensive and rapidly extending introduction of combination locomotive vehicles for railway purposes, termed generally "rail motor cars," as distinct from road traveling motor cars, is a most important feature of modern traffic methods quite apart from the engineering interest which attaches to the design of such vehicles. The "rail motor car" represents the solution of that most difficult problem of railway management,—a satisfactory method of dealing cheaply and yet sufficiently with the requirements of lines having light and comparatively unremunerative traffic in a fashion that will develop what traffic there is and induce other business.

The cheapest usual method of working country branch lines is to employ a small tank locomotive (generally an old one) with three or four coaches, one engine and train doing all the passenger work of the branch, and the same engine, if possible, dealing with the goods traffic as well, or the two being worked by "mixed" trains. It is even possible, in some localities, to use one engine and train for working two branches, running alternately on each; but this represents the extreme of economy, and can be but rarely practiced.

Nowadays, however, if a train service is to be really useful, the trains must be reasonably frequent, and the stations should be fairly close together; otherwise there is no encouragement for local travel, and there is a tendency for residents who have to travel to and fro frequently to use the roads, either for horse or bicycle transport, as the long intervals between trains entail more or less waste of time. Moreover, in opening up new districts, the traffic must necessarily be small for a long time, and it is too expensive a matter to employ two or three separate trains so as to give a frequent service. As a result, the building up of traffic becomes a slow process. Further, there are some districts where, although the traffic is not sufficiently voluminous to require the use of several trains, there is serious competition with electric tramways or motor-omnibuses. These latter possess the important advantages, from a resident's point of view, that passengers can enter or leave the vehicles almost anywhere desired, while railway stations, each with its own staff of officials and consequent cost of upkeep, are necessarily rarely less than a mile or a mile and a half apart.

With the advent of the rail motor car, however, most of these difficulties have been overcome, and its traffic facilities and conveniences may be briefly summarized as follows:—

1. There is a minimum of vehicles —one—and consequently a minimum of attendants, usually a driver, fireman (not always necessary) and a conductor or guard.

2. The train accommodation is designed for ordinary requirements, but trailer vehicles can be added when required, the motor car usually having sufficient reserve of power to allow of this addition.

3. The locomotive power is in accordance with requirements, whereas usually even the smallest tank en-

gines are considerably more powerful than is required for traffic such as a motor car can deal with.

4. No time is lost in reversing the engine, and a motor car can be kept almost continuously at work, so that all time paid for is profitably employed, while a frequent service is possible, thus providing one of the strongest inducements for local travel.

5. It is a simple matter to provide for intermediate stopping places, at highway crossings, etc., or at "haltes" (stations with short platforms, but no staff and office buildings), the conductor or guard collecting fares on the car in tramway fashion.

6. Such cars can most appropriately be used for opening up new districts, in consequence of the previously-mentioned advantages.

7. The facilities and conveniences for travel can be made to approach very nearly those provided on tramway and omnibus routes.

With regard to paragraph 5 above, it may be mentioned that on some of the light railways of Great Britain, and the numerous steam tramway routes of Belgium, Holland, and, to a less degree, other Continental countries, there are very similar facilities provided, and in the United States there is at least one instance where traffic is conducted with ordinary engines and vehicles in somewhat similar fashion (on the Chicago & Alton Railway, where short trains are run on routes competing with electric street railways, the trains stopping, when required, at highway crossings and near to principal buildings, etc.), but the employment of rail motor cars is a far more satisfactory practice, and is superseding other methods in many places.

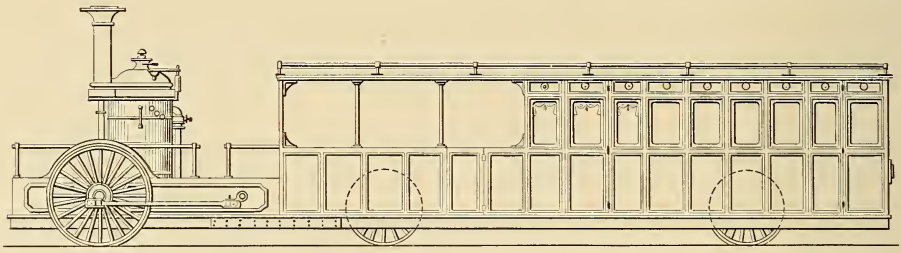


FIG. 1.—THE "FAIRFIELD,"—AN EARLY RAIL MOTOR CAR ON THE GREAT WESTERN RAILWAY

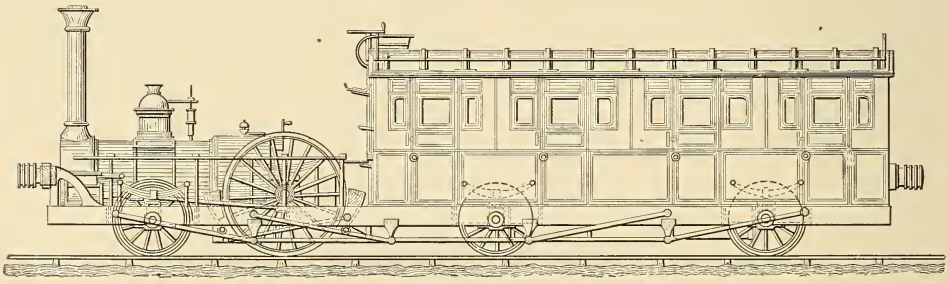


FIG. 2.—THE "ENFIELD," A RAIL MOTOR CAR USED ON THE EASTERN COUNTIES, NOW THE GREAT EASTERN, RAILWAY

It is often stated that the rail motor car is an example of "up-to-dateness," and so it is in many respects, for its employment is essentially a characteristic of twentieth century methods, and the vehicles now employed are good examples of modern

engineering, but the use of such vehicles is a very old practice in Great Britain, and they have been employed for many years in some parts of the European Continent, while a few instances of their use are to be found in the history of American transportation. In design, however, the rail motor car is a modern production, and the spasmodic introduction of such vehicles during the past fifty or sixty years can hardly be compared with their present systematic employment. Before dealing with modern vehicles, however, it will be interesting to consider briefly a few of these early vehicles, if only for purposes of comparison.

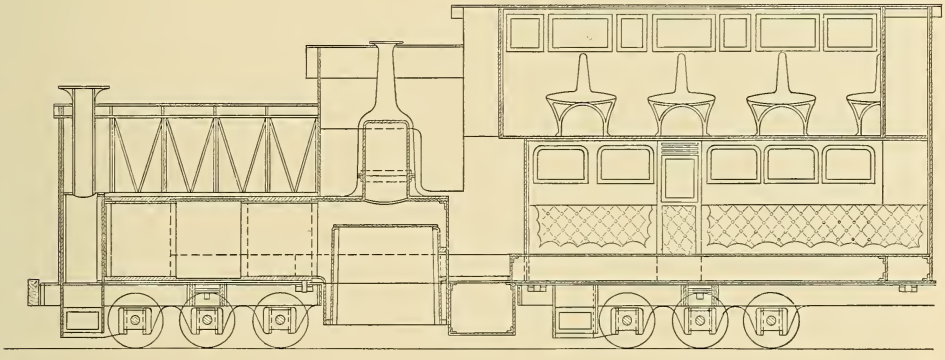


FIG. 3.—AN EARLY DESIGN OF RAIL MOTOR CAR BY MR. J. F. FAIRLIE, THE PRINCIPAL INTRODUCER OF THE DOUBLE-BOGIE LOCOMOTIVE

As long ago as 1847 a rail motor car was in use on the Eastern Counties (now the Great Eastern) Railway. This peculiar little machine was only 12 feet, 6 inches long, and this length comprised the engine and a small compartment for seven passengers. This marked the commencement of an era of rail motor cars in Great Britain, and quite a number of such vehicles were introduced, but this lasted a short time only, for after two or three years' use these cars were superseded, principally because traffic had outgrown their usefulness, and, secondarily, because what were termed "light" locomotives (very small tank engines) were extensively employed to the supersession of the motor cars.

In Figs. 1 and 2, reproduced by permission of Mr. William G. A. Sekon, editor of the "Railway Magazine" and author of "The Evolution of the Locomotive," two of the more noteworthy of these early cars are illustrated.

The "Fairfield," Fig. 1, was designed and built by Mr. W. B. Adams for service on the Tiverton branch (7-foot gauge) of the Great Western Railway, and commenced work at the end of the year 1848. A vertical boiler was used, and the engine drove a dummy shaft coupled to a pair of 4-foot 6-inch wheels. The length of the complete machine was 39 feet, and this included a first-class compartment in the form of a closed saloon for sixteen passengers, and two second-class compartments, one closed and one open, for thirty-two passengers. After some months' use, the vertical boiler was replaced by a horizontal locomotive boiler, but eventually the car was dismantled, the engine portion being converted to a small tank locomotive.

Shortly after this, the "Enfield," Fig. 2, was built for use on the Enfield branch of the Eastern Counties Railway, and this worked all the traffic, including goods and coal, of the branch for some time. It will be interesting to mention that the

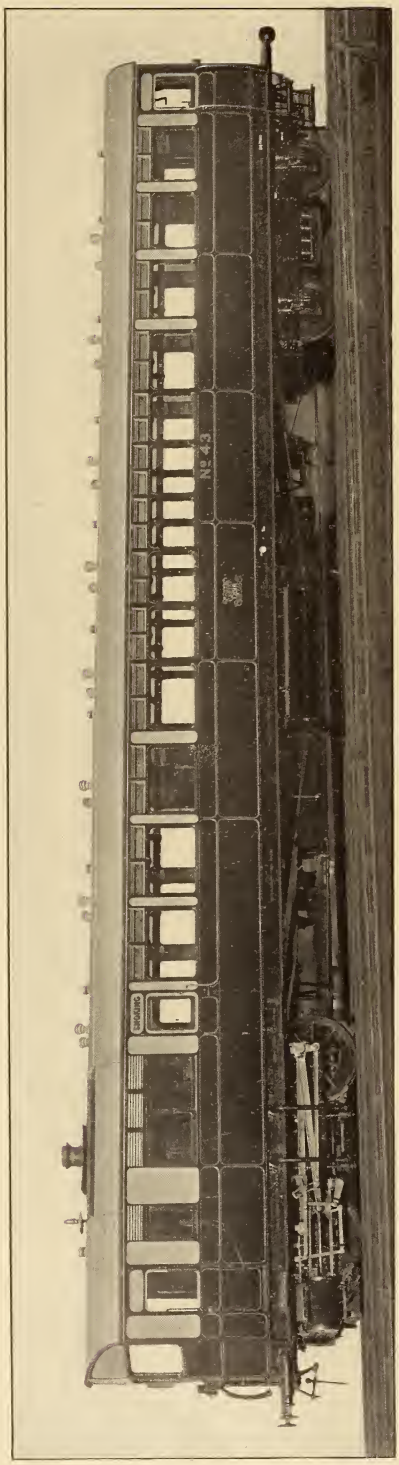


FIG. 4.—A 70-FOOT CAR FOR SUBURBAN SERVICE ON THE GREAT WESTERN RAILWAY

Enfield line is now one of the busiest sections of the Great Eastern Railway, and at some periods six or seven heavy trains are now required in an hour.

In the "Enfield" the car comprised practically a small single driving tank engine with 5-foot driving wheels, combined on one frame, with a four-wheeled coach accommodating forty passengers, the guard having a seat on the roof at the front end. For some time, as traffic grew, two additional vehicles were hauled, seating a total of 150 passengers, but after about two years ordinary trains were substituted.

Another car of like character, but having the engine separately connected with the vehicle portion, as is now done with several recent cars, ran on an Irish line, and accommodated 130 passengers, though presumably a trailer vehicle was necessary to enable this to be done.

Before dealing with modern practice, a scheme suggested by Mr. J. F. Fairlie, best known as the principal introducer of the double-bogie locomotive, may be mentioned, and a drawing representing this arrangement is reproduced in Fig. 3. The writer believes that one or two such vehicles were actually introduced for colonial lines, where the absence of bridges made the two-story design possible. In this case there were two driving bogies, each having six coupled wheels, as the design was intended for steeply-graded lines; the lower saloon was for first-class passengers, and the upper section for second-class passengers. Luggage and fuel were to be carried over the boiler, and the driver's cab was located over the fire-box alongside the steam dome.

At intervals during the past fifty years the rail motor car has been revived in various parts of the world, but sufficient has been said as to early practice in this connection, and attention will now be directed to modern designs and methods.

For recently-designed rail motor

FIG. 5.—INTERIOR OF THE CAR SHOWN IN FIG. 4

cars at least six distinct practices are followed as regards the main features of design, though only a general classification can be made. These may be described as follows:—

STEAM

A.—Vertical boiler, engine and vehicle on one frame.

B.—Horizontal locomotive type boiler, engine and vehicle on one frame.

C.—Small locomotive separately attached to the vehicle, though not intended to be run independently, and only disconnected for repairs and special purposes.

GASOLENE OR PETROL

D.—These vehicles are designed with an engine of motor-car type, connected with the driving wheels through gearing.

GASOLENE-ELECTRIC

E.—These vehicles comprise practically a traveling generating station,—a gasolene or petrol engine driving a dynamo which supplies current to motors on the axles. This apparently wasteful method of working is now finding considerable favour. It has the important advantage that motor-equipped trailer vehicles can be supplied with current from the main car, a facility which, although of little value at present, may be a prominent factor in the future.

ELECTRIC

F.—Operated by electric motors supplied with current from accumu-

FIG. 6.—A LARGE BOGIE CAR BUILT BY THE PEEBLES STEAM CAR CO., LTD., LONDON

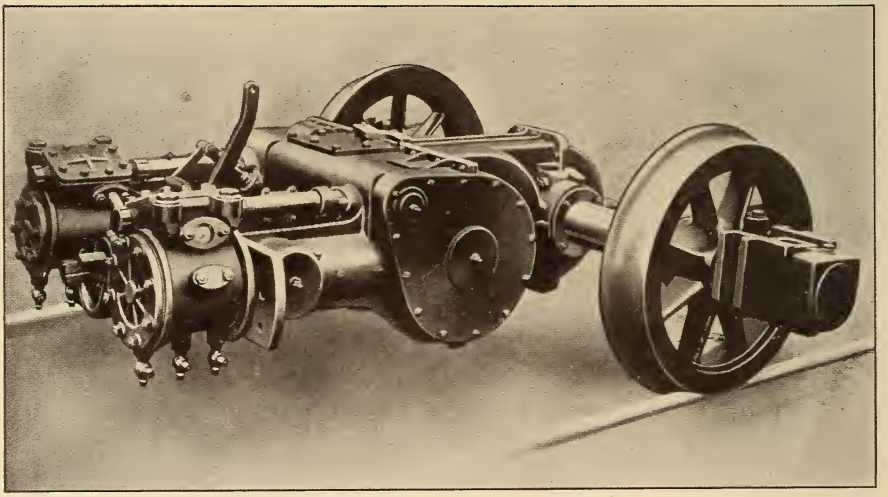


FIG. 7.—THE ENGINE, GEAR BOX, AND DRIVING AXLE OF THE CAR SHOWN IN FIG. 6

lators. Very few of these vehicles are in use, and these are mainly experimental.

If supplied with current from external sources, electric cars become electric railway or tramway vehicles, and are therefore outside the scope of this article, because they are not then self-contained units. A few attempts have also been made to employ compressed air as motive power. The classification previously given will be followed throughout the remainder of this article.

In Great Britain, the large majority of the now numerous rail motor-car designs belong to sections *A* and *B* of the classification, and representative examples of each practice will now be described.

The first line to employ a rail motor car of modern design in England was the London & South Western Railway, whose original car was in-

troduced for working traffic on a branch owned jointly by that railway and the London, Brighton & South Coast Railway. This car had a vertical boiler. In this design, however, a special design of boiler, built on the lines of the multitubular boiler, has since been substituted, and is employed for new cars, so that South Western cars should now be classified in section *B*.

The most prominent user of section *A* vehicles, and, indeed, of any type of motor coach, is the Great Western Railway. Figs. 4 and 5 illustrate one of their latest vehicles. According to this design, a vertical boiler is employed, mounted on a driving bogie, arranged at one end of the car. The arrangement in which the boiler practically formed the pivot of the bogie has been the

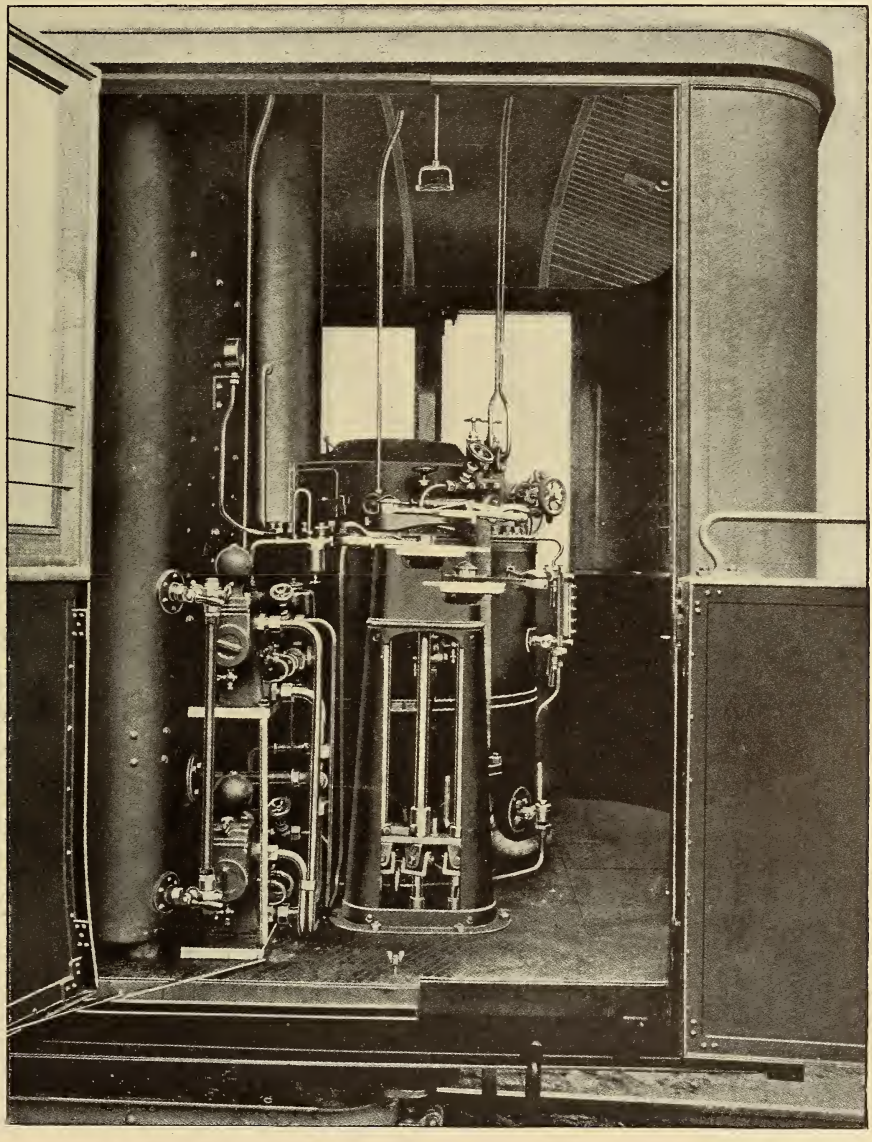


FIG 8.—THE DRIVER'S COMPARTMENT OF THE CAR SHOWN IN FIG. 6

cause of some weakness in course of time, and therefore considerable alterations in this respect have been made in recent vehicles. A small two-cylinder engine on the driving bogie actuates one pair of wheels. At the rear end there is a driver's compartment, from which the driver can operate the car when that end is leading, flexible connections being employed for transmission from the controlling levers to the engine compartment.

Since the introduction of these vehicles, which are now more than forty in number, the Great Western officials have employed them for varied purposes. A car has been run for several years in between the ordinary trains on a country section of one of their main routes, and this car stops at intermediate road crossings to discharge or take up passengers. A similar purpose has been achieved on other lines by the building of what are termed "haltes,"—a useful word, derived from the French. These "haltes" are built up platforms about 100 feet long, with a small shelter for waiting passengers, but no booking offices or staff, and the cars stop at these when required, the conductor collecting fares and issuing tickets.

A new main line out of London is now under construction for the Great Western Railway, and for over twelve months local traffic has been carried over the first few miles of this line by means of rail motor cars, thus efficiently opening up new districts in a cheap fashion. These cars run on a circular service embracing a portion of the ordinary main line. Two cars are used for the service, one car working on one route, and the other on another route, and both of them are kept at work almost continuously, there being very short intervals between trips,—in some instances three or four minutes only. In connection with the opening up of this new line a somewhat curious practice has arisen, for on Sundays the cars start from Clapham Junction (London, Brighton & South Coast Railway) and travel via Addison Road on a special service to the new line over routes for which there is no equivalent on week days. These trains are advertised for Sunday excursions, and are very popular, it being sometimes necessary to run two cars coupled together.

In the Plymouth district there is quite an elaborate service of rail motor cars over several routes. On ordinary branch lines the use of the cars has enabled a frequent service to be maintained, almost doubling the number of trips run by the locomotive and train previously employed. On at least one branch line in the West of England the car works only on the branch for part of the day, a locomotive train taking its place for the remainder of the day, the car being then employed for short runs along the main line in between the long-distance trains.

A more detailed description of the Great Western cars will now be given, and such description will, in many particulars, serve as an indication of the ordinary characteristics of most other cars. The car illustrated in Figs. 4 and 5 is of the latest design employed on this railway. The earlier cars were somewhat shorter, but as regards the engine and boiler, except that a few alterations have been made in the latter, the earlier practice is followed. On this line no provision is made for more than one class of passengers, and where these cars run over sections having ordinary trains as well, a notice is given in the time tables, "Rail Motor—One Class Only." There are, however, two classes of these vehicles, the one adapted for ordinary branch lines having luggage accommodation, and the other intended for suburban traffic, having greater seating area without a luggage compartment.

Fig. 4 shows one of the suburban cars, and Fig. 5 is an interior view. These are 70 feet long and 9 feet

wide, with an internal height of 8 feet. They are divided into the following compartments: a motor compartment 14 feet ⅜ inch long, a passenger compartment 47 feet 7¼ inches, and a vestibule 4 feet 9 inches. The passenger compartment will seat sixty-four passengers, twenty-four in walk-over cross-seats towards the center, eight in fixed cross-seats, and thirty-two in longitudinal seats towards each end. The divisions of the longitudinal seats and the end of the cross-seats are of polished oak, and support arm rests. The seats and seat-backs are composed of woven wire, three cars being covered with leather, three with rep, and four with rattan.

Large windows are arranged at each side of the compartment, each having two ventilator lights above, which may be opened or closed by the passengers. Spring blinds are fitted to the large windows. The cars are constructed of teak and Baltic and Canadian oak, the outside being panelled with Honduras mahogany, and the inside cased with pine. All interior finishing work is in polished oak. The roof is panelled and moulded, and painted white, the mouldings being picked out in blue. Two brass rails supported by pendants fixed to the roof, run from end to end of the passenger compartment; to these are attached leather hand-loops for the assistance of passengers.

At the vestibules, which are at the ends of the cars, hinged swing steps controlled by the conductor are provided for the convenience of ingress and egress at the rail level. Hinged doors are fitted in the vestibule and also at the opposite end of the passenger compartment. Communication between vestibule and passenger compartment is by means of polished oak sliding doors. The cars are lighted by oil gas lamps of 14 candle-power each; the gas is contained in cylinders attached to the underframe. There are eight duplex burners in the passenger compartment, one in the vestibule and two in the motor compartment. Numerous ventilators are fixed in the roof of the cars. The underframes are constructed of mild steel, each carried on a four-wheel suspension-hung bogie at the motor end of 8-foot wheel-base, and a bolster bogie at the trailing end of 9-foot wheel-base. The total wheel-base is 57 feet 2 inches. The cars may be driven from either end; there is also electric communication between the vestibule and motor compartment.

The branch cars, which correspond in most particulars with the suburban cars, have a luggage compartment 6 feet 3 inches long, and this has flap seats provided, sufficient for five passengers when luggage is not being carried. The passenger compartment is only 43 feet 6 inches long, and seats fifty-eight passengers.

Owing to the increase of traffic on several sections, and to obviate the practice of coupling two cars togther, which otherwise becomes necessary only on occasions, specially-built trailer cars have recently been introduced. These are very similar to the motor cars in general appearance, but accommodate about ninety passengers. When coupled with a motor car the combination train can be controlled from the rear of the trailer when that end is in front.

On the Furness Railway special trailers have also been introduced, these being six-wheeled cars, but on most other lines ordinary coaches are added when necessary. Cars of similar type are used on several other British railways, of which might be mentioned the Midland, Furness Great Central, and several Irish lines.

Vehicles of similar type are also being introduced by Messrs. Kerr, Stuart & Co., Ltd., of London, and some interesting examples of large-size cars have been supplied by them for use in India. In one instance, a corresponding design has been

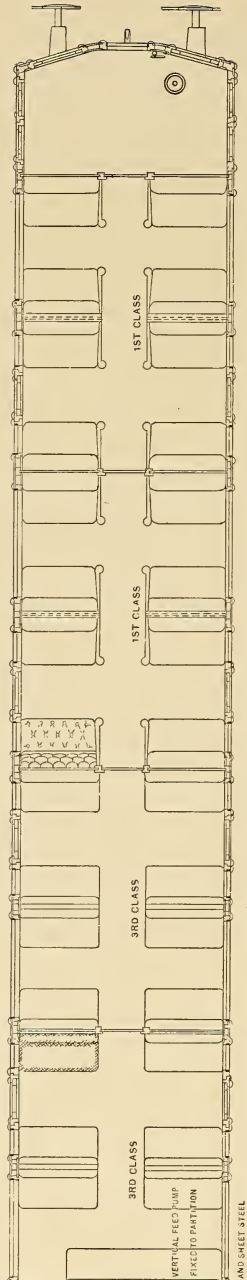


FIG 9.—A LARGE COMPOSITE STEAM MOTOR CAR BUILT BY THE BRUSH ELECTRICAL ENGINEERING CO., LTD., LOUGHBOROUGH

adopted as a traveling saloon for the use of an Indian potentate upon a private narrow-gauge railway.

Rail motor cars have been employed for several years in considerable numbers on Hungarian and German railways, including one which is numbered amongst the interesting series of experimental cars owned by the Wurttemburg State Railways, already referred to. Also designs introduced by the well-known firm of Ganz & Co., of Buda Pesth, and cars of similar build are now being introduced into Great Britain by the Peebles Steam Car Co., Ltd., of 25 Victoria street, London, S. W., under the style of the "Peebles" car. In this design a vertical boiler is employed, located in an engine compartment at one end of the vehicle, but, unlike other steam cars described in this article, the engine does not drive the wheels of the driving bogie directly, but is of a high-speed compound type connected with the driving axles through gearing.

Fig. 6 shows a Peebles car of the class which is used most generally on the Continent, but adapted for use on English railways, and this particular vehicle is being experimentally employed on the Midland Railway. Fig. 8 is a view showing the interior of the driver's compartment, and Fig. 7 shows the engine and driving axle.

A specially-designed water-tube boiler supplies steam, usually superheated, to a high-speed, two-cylinder, cross-compound engine having steam jacketed cylinders and connected with the driving axle through clutches and gearing. The engine is hung from the under frame of the car much as an electric motor is suspended, and is separate from the boiler; it is thus possible, by loosening a few bolts, to remove the engine and gearing with great ease and without interfering with the truck and wheels.

The engine crankshaft carries two spur wheels, each of which engages

FIG. 10.—A CAR BUILT BY R. Y. PICKERING & CO., LTD., OF WISHAW, FOR THE KENT & EAST SUSSEX RAILWAY

permanently with wheels on an intermediate shaft to give two speeds. Clutches are provided whereby either of these gears can be employed, one or other of the spur wheels being clutched with the intermediate spindle, so as to drive a third spur wheel which gears with a large wheel on the driving axle. The engine is provided with a by-pass valve which assists starting, and also allows of live steam being supplied to the low-pressure cylinder for temporary requirement. Reversing is effected by reversing the engine.

The motor is hung from the framework by means of springs, flexible steam-pipe connections being employed to allow of the requisite movement round the bogie pivot. Universal joints are fitted to the operating rods for controlling the clutch and for other purposes. In the case of larger cars, two motors are fitted, each with its own boiler, but the two boilers are usually located in the one compartment, though provision is made in both single and double-motor cars for controlling from either end. The car-bodies vary, of course, according to dimension and requirements, but in the largest of them, seating accommodation for 100 passengers is provided. In some cases steam heating and acetylene lighting are arranged for.

Fig. 9 illustrates a larger car which is now being built by the Brush Electrical Engineering Co., Ltd., of Loughborough, for the Peebles Steam Car Co., Ltd., and which is intended for use on an English railway. It is 60 feet long over buffers, and comprises four passenger compartments, two for first-class, two for third-class, and seats altogether 64 passengers. The driver's compartment, with two boilers, is only 5 feet 3 inches long. A corresponding compartment at the other end of the same length serves for luggage, and is fitted so that the driver can control the car from that end when running backwards.

Fig. 10 shows a Stephens-Pickering car recently built by R. Y. Pickering & Co., Ltd., of Wishaw, for the Kent & East Sussex Railway, according to the designs of Mr. H. F. Stephens, managing director of the latter company. Steam is generated in a vertical multi-tubular boiler. The engines have a pair of $5\frac{1}{2}$-inch cylinders, and are connected at the boiler by a flexible pipe, enabling the position of the engine to be adjusted to take up slack between the driving shaft and the driving-wheel axle. The shaft and axle are

coupled by a "Renold" chain. Steam can be shut off and the car braked from either end, signals being used for the reversing of the engines.

In the car illustrated there is accommodation for 31 passengers of one class,—11 smoking and 20 non-smoking passengers. There is also a luggage compartment, which has accommodation for the usual quantity of passengers' luggage, and for light parcel traffic. This compartment, having folding seats, can be used in an emergency for additional passengers, of which it will accommodate ten. Since the building of this first car, improvements have been made by employing a boiler of higher duty, and engines of higher speed. This has enabled them to be made smaller, and consequently to occupy less space in the car.

The concluding part of this article, to appear in the October number, will take up additional steam car examples, and gasolene, gasolene-electric, and electric designs.

SUCTION GAS PRODUCER PLANTS

By Dr. Oskar Nagel

THE use of suction gas producer plants is not fundamentally new. Suction producer gas is not a new gas, as it quite frequently is supposed to be. This error is made by calling the gas "suction gas," instead of "suction producer gas." This last name shows distinctly that the new point is not in the quality of the gas, but only in the way of its manufacture.

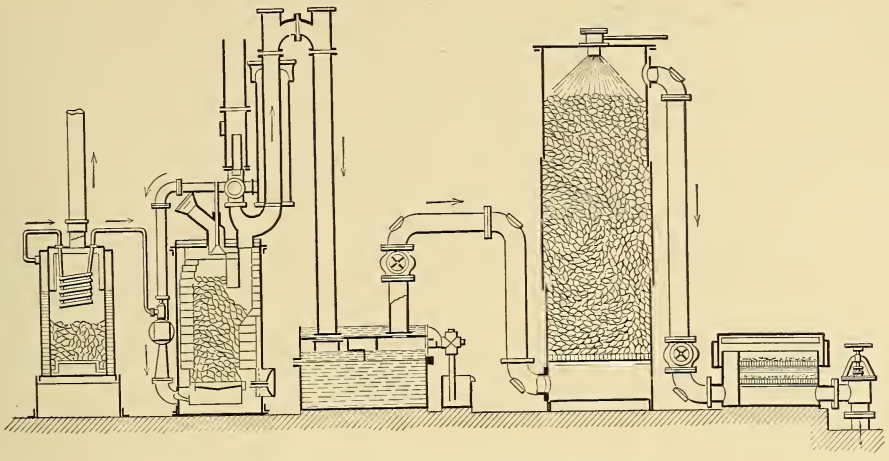
Producer gas used in gas engines was known for many years to furnish a power much cheaper than steam, but even with this well-known economy the use of producer gas was very limited up to a few years ago, because the ordinary gas producing plant (pressure gas producing plant) was complicated for sizes below 100 H. P., and also because the coal consumption was considerably decreasing in large steam plants, diminishing thereby the difference in cost in favour of the gas.

Another reason for the limited use of gas producers at that time was the limited size and limited power of the gas engine. On account of the simplicity and low first cost of the new suction gas producers the use of the power gas has been largely increased. The direct transformation of the heat of the coal into mechanical work, which is effected in the most economical way in producers that are connected to gas engines, is now also made possible for small plants and shops, and can be used by every small user of power. This explains the wide interest in power gas at the present time.

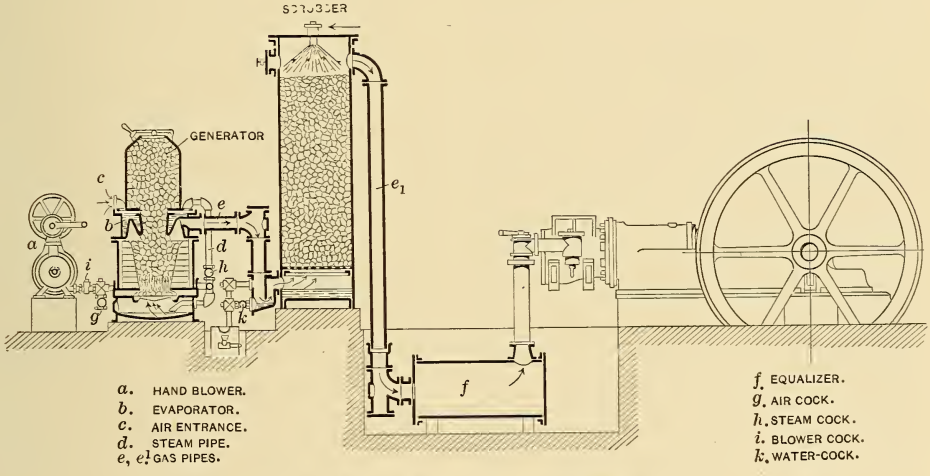
The ordinary pressure producer gas was generated by blowing air through a high fuel bed whereby carbon monoxide was formed. As in this reaction heat is generated, it was important to find a way for utilizing the heat. This was done by leading to the producer, together with the air, a certain quantity of steam which was decomposed by the glowing fuel into hydrogen and carbon monoxide; in this reaction the free heat from the first reaction was absorbed and the quality of the power gas improved. The resulting gas has the following composition:—

CO_2	5 per cent.
CO	26 per cent.
H	17 per cent.
N, etc.	52 per cent.

Even then the gases left the producer at a considerable temperature, carrying away about 10 per cent. of



A CONVENTIONAL PRESSURE GAS PRODUCER PLANT



AN EXAMPLE OF SUCTION GAS PRODUCER PLANT

the thermal value of the coal. It was, therefore, the aim of the engineers to utilize this heat for the generation of the necessary steam for which, up to that time, an independent small boiler was used. By utilizing this waste heat for the generating of the necessary steam, the loss of 10 per cent. is reduced to about 4 per cent.

In generating the steam by the waste heat of the gases, entirely new conditions arose, as there was no pressure at disposal and it was impossible to carry the air through the producer by means of a steam jet blower. Experiments were therefore made to carry the air to the producer by means of a fan, and at the same time suggestions were made to utilize the movement of the piston of the gas engine for supplying the necessary amount of air.

In 1891, Benier took out a patent for a producer from which the gas was drawn by a gas engine. In 1895, C. Wiegand took out a German patent, according to which the suction principle was to be used. It is therefore apparent that the fundamental ideas relating to the utilization of the heat and the suction principle of the

suction gas producer, are not at all new. The details of construction, however, were worked out at different places at the same time, and it is hardly fair to talk of one single firm or engineer as the inventor of suction gas producers.

In the pressure gas plant a steam boiler, the steam of which is mixed with air in the steam jet blower, is forcing a mixture of steam and air through the grate of the producer; by going through the glowing fuel, producer gas is formed, which, when leaving the producer, has a temperature of about 900 degrees F. It is then led through a water-seal, the wet scrubber, and sawdust scrubber to the gas holder, and from there to the place of its use. The pressure under the grate is about 10 inches, and in the holder about 2 inches.

Many improvements relating to the dimensions and shape of the producer, and the generation and superheating of the steam, etc., were made in the course of years on these plants. At the same time experiments were made relating to the gas engine, which, up to that time, had been mostly worked on illuminating gas, and which had to be changed in several respects according to the requirements of the new power gas. All experiments that were made on the pressure gas producers were naturally utilized when the suction gas producer came up. Although great improvements have been made in pressure gas producer details, a modern producer plant consists essentially of the same parts that made up the original outfit,—that is, a boiler, producer, water-seal, wet scrubber, sawdust scrubber, and gas holder.

In the suction gas producer plant, on the other hand, only two parts remain from the six parts of the pressure gas producer. These two parts are the producer and the scrubber. In place of the boiler we find an evaporator which is on top of the producer. This evaporator is a cast-iron evaporating dish filled with water, and provided with an overflow. The water is kept hot (about 200 degrees F.) by the radiating heat of the fuel in the producer, and by the hot gases that are surrounding the evaporator. The air in traveling over the surface of the water is thereby saturated with vapour, and the mixture of vapour and air goes through the grate and the fuel, being transformed into gas and leaving the producer after heating up the evaporator.

The purification of the gas is considerably simplified as the sawdust scrubber is done away with, the whole purification being performed in the wet scrubber. The gas holder also has been removed as it is not necessary to have this apparatus in the suction system.

The suction gas producer plant works as follows:—

Before starting up the engine, the fire in the producer, which is in a glow from the previous day, is blown hot by means of a hand blower until the gas is burning well at the test cock. This requires about ten minutes. During the time of running, the engine sucks the gas from the small equalizing tank, which is a plain iron drum, so that a vacuum of about 8 inches is created in the equalizer; the gas is thus flowing to the equalizer from the scrubber and shows at the entrance to the scrubber a vacuum of about 4 inches. This vacuum is sufficient to draw air through the evaporator, which, in going through the fuel, is converted into new gas.

Comparing these pressures with the figures in the pressure gas plant, we find them changed about 8 inches, but the difference in the pressures inside the apparatus has remained constant. Attendance is now practically unnecessary. Coal which has to be introduced in pressure gas producers very frequently, is put into the suction gas producer at intervals of 5, 6, or even 10 hours. The water is kept slowly running into the evaporator, the excess going through the overflow under the grate, thereby

keeping the grate bars cool and prolonging their life.

Experiments were also made to generate the necessary steam in an independent tubular evaporator which was set between the producer and the scrubber. But it was found that it was not advisable to use this system for the small sizes, say below 75 H. P., as it was difficult to keep up the necessary amount of steam without making the tubes too small in diameter. If the tubes are too large, the heating surface is not sufficient; if the tubes are too small, considerable trouble is encountered by sediment in them, and it takes a long time when starting up to get the necessary amount of steam. Thus it is that many systems of suction gas producers are using a simple evaporator on top of the producer, which insures an equal evaporation and a good working of the producer.

Comparing the suction gas system with the pressure system, the former is much simpler, and what is more important, much safer than the pressure system. No poisonous gas can leak out into the atmosphere from the suction gas producer on account of the negative pressure. The pressure system does not generate a better or a stronger gas than the suction system. Explosions by leakage of air into the suction gas apparatus are practically excluded. There are only a few valves to be handled, and the attendance is very simple.

In Germany suction gas producer plants are considered much safer by the insurance companies than steam boiler plants, and may be put into any apartment houses, stores or shops. A suction gas producer plant has not at all the nature of a gas manufacturing plant, as no stock of gas is kept on hand, and as the engine is making only as much gas as it needs.

As to the amount of floor space required, suction gas producer plants are very much to be preferred to pressure plants, as the large space for the gas holder is saved.

In reducing the floor space required by a suction gas producer plant it is of importance to reduce the gas purification as much as possible. The main impurity in anthracite and coke is the tar contained in these fuels, which does not have any effect on the wear and tear of the engine. The tar that is not removed in the scrubber settles in the inlet valve and in the cylinder of the engine. Therefore, the valve has to be of such shape that its working is not interfered with by small amounts of tar. However, these parts have to be cleaned from time to time to insure satisfactory and continuous running. In small plants it is of advantage to clean the inlet valve about once a week; this can be done in a few minutes. The piston has to be cleaned about once in two months.

For suction gas producers with which, as a rule, especially in small-size plants, work is carried on for not more than 10 or 12 hours per day, it would not be advisable to put in a large purifying plant which has to be kept in running order, and which might cause stoppages. The question to be answered is, whether it is preferable to put in a large purifying plant which involves some running and operating expenses, or to clean regularly a few parts of the engine that are exposed to the dirt.

As for small plants simplicity is of great importance, it is better not to use any sawdust scrubber, although it is of great advantage, and in fact a necessity, for large-size plants. In small plants the sawdust scrubber will take up comparatively too much space, and it will take just as much work to keep the scrubber in order as it will take to keep a small gas engine clean. It is a question, therefore, whether it is preferable to attend to a sawdust scrubber or to open and clean a valve inlet. At one of these parts, of course, the tar has to be removed. A certain degree of purity is essential, and care has to be taken in the construction of the scrubber and producer that the limit

of impurity is not exceeded; but this depends mainly upon the quality of the fuel. The better the fuel, the smaller need be the purifying plant.

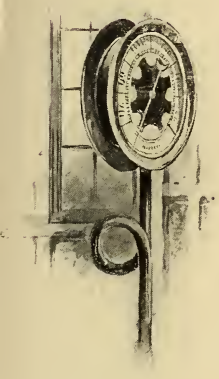
The coal consumption in a suction gas producer is about 10 per cent. less than in a pressure gas producer, as the necessary steam is generated by the waste heat of the producer, whereby the efficiency of the producer is increased to 75 or 80 per cent. One brake horse-power is developed from 0.9 to 1.2 pounds of coal. This shows that power can be generated at very little cost in suction gas producers. Even with a low price for boiler coal, and a high price for producer coal, producer gas power is considerably cheaper than steam power. This holds good for small, as well as large plants. The first cost of a producer gas power plant is about the same as that of a first-class steam power plant.

The suction gas producer is a strong competitor for other sources of power. However, a certain field will always be reserved for the steam engine, illuminating gas engines, and gasoline engines as the suction gas producer is of advantage only in such places where the engine is not working much less than 3000 hours a year. In certain places there will be conditions which will be in favour of steam plants or an illuminating gas engine; on the other hand, the uses of producer gas will grow, as it will be employed in places where part of the gas is required for heating and fuel purposes, or where it is desirable to do away with a chimney, or in places where it is essential to get power on short notice, which is the case in reserves for water-power plants. Suction gas producer plants are especially adapted for electric light plants of small size, and the fuel economy in small plants is the same as in large plants.

The advantages of suction gas producers are:—The plants are cheap, simple, and do not require any expensive repairs; the fuel cost is exceedingly low; the floor space required is very small; a plant can be erected in any building; there is absolutely no danger in the running of gas producers; a gas producer plant can be started quickly; the attendance is simple; and there is no smoke nuisance.

STEAM BOILERS WORKED BY WASTE HEAT FROM COAL-FIRED REVERBERATORY FURNACES

By the Late R. T. Cooke, M. I. M. E., and Percival Cooke



MANY boilers heated by the waste heat of reverberatory furnaces are overburdened with heat because the furnace exit flues are either built, or worn, too large, thus allowing the heat to escape too freely from the hearth of the furnace before it has done a proper amount of work.

The safety and durability of the boiler demand that the furnace shall be kept in proper repair and adjustment. To insure good, economic working, complete combustion of the fuel is necessary, and the heat thus produced should be kept in the furnace long enough to do the work for which it is generated, and not hurried off prematurely to the boiler and chimney.

Figs. 1, 2 and 3 show sectional views of a properly arranged reverberatory furnace of the type most commonly used. The first essential is to have the furnace hearth *B* quite suitable for the work to be done, after which the fire grate *A* and the flue exit *C* should be made in proper proportions relatively to the hearth. For ordinary furnaces, as used in puddling and rolling mills, the area of the fire grate should be from 0.33 to 0.50 the area of the hearth, according to the quality of coal used, while the flue exit *C*, often called the "gauging," should be 0.10 the area of the fire grate, and in shape as shown in Fig. 2, which is a transverse section through the hearth at the center of the doorway. The high temperatures at which these furnaces work is obtained by burning the coal with the practical minimum of air, which may be done with closed ash pits and steam jet blowers.

If the fire grate and the flue exit are of the proper shape and area relatively to the hearth, and the steam jet blowers adjusted to volatilize the coal no quicker than the products of combustion can burn, a clear white-hot hearth will result.

If the hearth works too cold when the whole furnace is of proper construction and in good repair, the blowers are either too powerful or the fire grate and flue exit are too small. If the adjustment of the blowers and volatization do not give good results, the fire grate and flue exit should be enlarged until good economic working is obtained. A good plan is to build the flue exit separate from the hearth, as shown in Fig. 4; this admits of easily and conveniently enlarging or reducing its area, according to requirements, although the proportion previously stated should be adhered to as closely as possible.

If a slight plenum or pressure of gas is maintained over the hearth, the smallness of the flue exit will cause the products of combustion, or furnace gases, to reverberate back from the flue over the hearth again, the greater part of the smoke thereby being burned and a high temperature obtained.

This method of working the furnace is not only economical, but it also prevents the boiler from being overburdened with heat. Considerable damage is often done to furnaces and chimneys by employing a

greater draught than is really necessary for the work, and much fuel is wasted by allowing volatilization to take place quicker than the products of combustion can burn. Whatever class of boiler is attached to a furnace, the heat current should be so regulated as to dwell a little upon

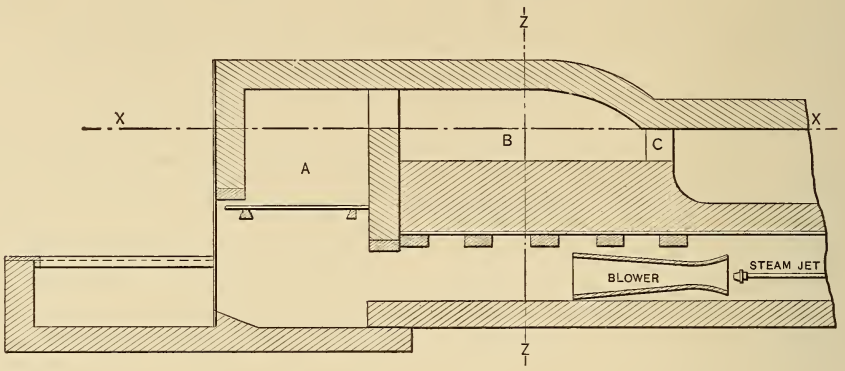


FIG. 1.—LONGITUDINAL SECTION OF A PROPERLY ARRANGED REVERBERATORY FURNACE

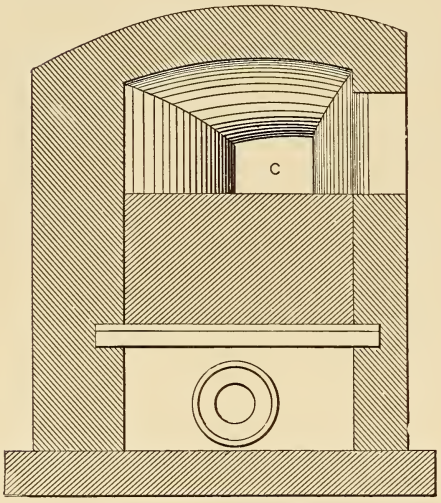


FIG. 2.—CROSS SECTION AT ZZ, FIG. 1

the boiler by moderating the draught to the practical minimum limit that the work will allow. Steam jet blowers that are too powerful will gorge the fireplace, furnace, flue, boiler, and chimney with dull-red or orange-colored flame that will ooze out of all crevices in the brickwork and do much damage to all parts of the furnace and brickwork flues. The greatest wear and damage, however, result from closing the furnace damper and leaving the blowers at work full force. This is an altogether unnecessary and inexcusable practice. For good economic working, the blowers must be properly regulated to the requirements of the furnace, the flue exit must be small in area, and the heat current leaving the boiler should

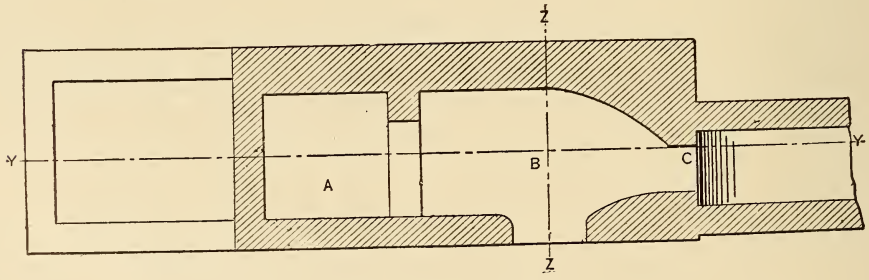


FIG. 3.—HORIZONTAL SECTION ALONG XX, FIG. 1

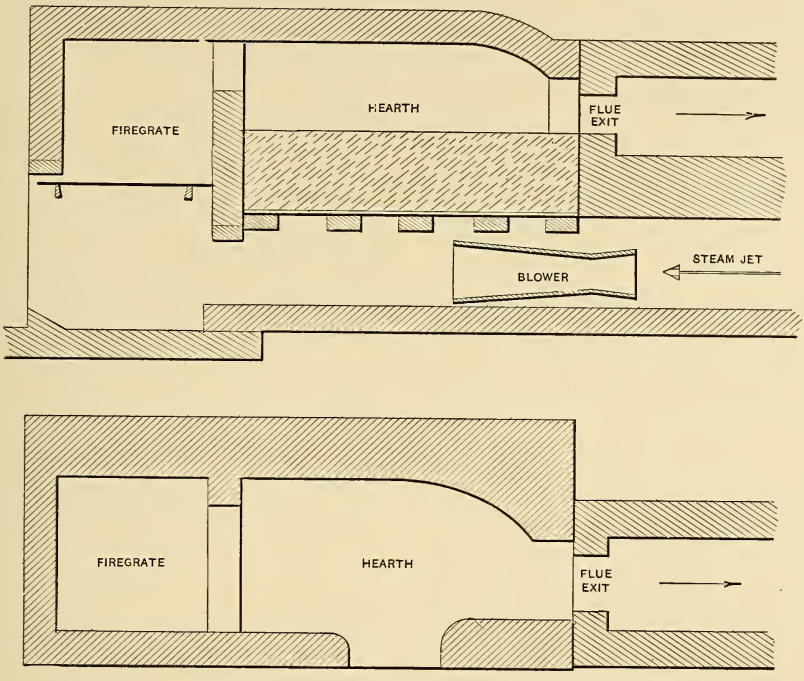


FIG. 4.—SECTIONAL PLAN AND ELEVATION OF A REVERBERATORY FURNACE, SHOWING IMPROVED CONSTRUCTION OF FLUE EXIT.

be retarded by a stricture in the flue, the area through which should be reduced to the practical minimum, which can only be found by trial. It should be reduced till found too small, and then gradually enlarged until good working is obtained.

THE BABCOCK & WILCOX BOILER

There is no denying the great steaming capacity of this boiler when attached to a rolling mill or forge furnace. No other boiler is so well worthy of careful attention and good rational management.

The heat current should be well distributed over the whole available area of the bottom row of tubes, and the brickwork partitions for directing it should be kept in good condition, in order to secure a good uniform distribution of heat over the whole of the tube heating surfaces. These should be kept free from dust and soot by thorough application of the steam brush every twelve hours' working shift. This simple expedient, though most important, is often neglected, with consequential dusty and sooty tubes and considerably reduced steaming power. A good staging should be erected for the convenient use of the steam brush by the boilerman; there will then be less chance of its use being neglected.

In order to prevent loss of heat by radiation, the steam drum surfaces should be well covered with some good non-conducting material. The boiler should always be fed with hot water; in fact, no pains should be spared to bring the feed water to as high a temperature as possible, for in this lies the great secret of economic steam production. The draught should be checked during the cleaning of the fire grate and cooling of the furnace in order to prevent the boiler from being flooded with cold air.

The cleaning of the water in steam boilers while at work is a matter of

very great importance, although it is often overlooked both in actual practice and in boiler literature. The continual cleaning of the water by blowing down is capable of turning failure into success in water-tube boilers worked with dirty feed water. It is, in fact, the most important factor in the working of all boilers, water-tube or otherwise.

To obtain the best results it should be done every twelve hours, if possible after the boiler has rested half an hour, as this allows the mud and sediment to settle to the bottom of the boiler or mud drum, as the case may be. Blowing the mud and dirt out of a boiler through a plug blow-off tap sets up a sand-blast action upon the tap which, in a short time, causes it to become very leaky, and before this method of cleaning the water in steam boilers can be used to full advantage a good blow-off valve must be designed that cannot be injured by this sand-blast action. It should be opened and closed with a screw, as the opening and closing of a plug blow-off tap under high pressure is dangerous and may lead to rupture of the tubes. Space does not permit of going into the subject of blow-off valves, the designing of which involves no small amount of engineering skill and ingenuity; but better blow-off valves than those usually employed ought most certainly to be provided—valves that the boilermen can open and close easily, conveniently, and without the slightest hitch or fear of accident. In fact, if blowing down under high pressure is made a pleasure instead of a danger to the boilerman, a great improvement in boiler working will be accomplished.

Returning to the Babcock & Wilcox boiler, in ordinary practice with very dirty water, the water level should be raised to the top of the glass gauge tubes, and blown down again to the working level every dinner time, and at the end of every twelve hours' working shift. At the end of each week's work, all the water in the boiler should be changed, after an hour's rest, by opening the blow-off and feed valves together. The water level should be left at the top of the glass gauge tubes for cooling during the night.

The next day the boiler should be emptied, well swilled out, and the mud drum opened for cleaning, although generally it will be found quite clean,—eloquent testimony to the value of proper blowing down. In closing up the mud drum, great care should be taken to see that the mud-cover joints are perfectly watertight; neglect of this simple precaution may lead to severe scalding of the boiler attendant. After closing up again, the boiler should be filled with fresh clean water for the ensuing week's work.

THE GALLOWAY BOILER

The Galloway boiler is especially suitable for attachment to reverberatory furnaces, its length and the number of cross-tubes in the main flue enabling it to absorb all the waste heat of any size of furnace. It can be made especially for attachment to reverberatory furnaces, the oval flue tube in this case running the full length of the boiler, the two furnace tubes required for internal firing being dispensed with. The heat-absorbing ability of the Galloway boiler is one of its best qualifications, giving an advantage which can be continually maintained if the cross-tubes and the water in the boiler are kept quite clean. Its efficiency, however, is much impaired by allowing the cross-tubes to become dirty. The water should be kept clean by frequent blowing down, and under careful management the cross-tubes will not be allowed to become dirty. Working this boiler for three or four weeks without blowing down, and then blowing down while hot and leaving the boiler empty for cooling, is a most direct way of reducing its efficiency to a low point. This reprehensible practice not only imposes severe stresses on the boiler, but also

causes the cross-tubes and the oval flue tube to become covered in places with hard-baked scale, difficult to remove.

In order to take full advantage of cleaning the water by blowing down, better blow-off valves must be provided than those usually employed, as in the case of the Babcock & Wilcox boiler. The remarks which have been made previously on the subject of blow-off valves apply specially to boilers of the Galloway and Lancashire types.

At the end of each week's work, after resting an hour, two-thirds of the water in the boiler should be changed by opening the blow-off and feed valves together. The boiler should be left nearly full of water for cooling, in order to equalize the contraction of the plates and tubes; the steam pressure should be reduced to zero; and the manhole and safety valves should be left open. On no account should the boiler be left empty for cooling. On the following morning the boiler, when cool, should be emptied and well swilled out with a water hose, the cross-tubes being given special attention. Although each cross-tube robs the crown of the main tube of more than half a square foot of heating surface, it much more than makes up for this, besides which it sets up excellent circulation of the water. Hence, again, it becomes of the utmost importance to keep the water and the cross-tubes quite clean, which is quite impossible under the ordinary monthly cleaning practiced in some works, where the boiler is blown off while hot and left empty for cooling.

In Galloway boilers fired with self-contained furnaces, the plates of the bottom flue should be kept quite clean and free from soot and dust.

Digressing for a moment to consider internally-fired horizontal boilers, whether of the Galloway type or otherwise, the flue gases, after leaving the main flue tube, should in all cases be led into the bottom flue underneath the boilers and then off to the chimney through the side flues, and not, as is occasionally the case, directed into the side flues first and then off to the chimney through the bottom flue. It is clear that more heat is required at the bottom of the boiler than at the sides, owing to the gravitation of the comparatively cold feed water; hence the reason for passing the flue gases underneath the boiler while rich in heat,—an arrangement which also facilitates convection.

No boiler should be fed with cold water while working. It is a common, but nevertheless reprehensible, practice to fill up with cold water at mealtimes and other short stoppages, as by doing so full steaming is suspended for from one to two hours. Before mealtimes boilers should be filled up while hot water is available to such a height that the water level will return to the pointer by the time of restarting.

When the Galloway boiler is attached to a reverberatory furnace, the furnace requires the same care and adjustment as that to which the Babcock & Wilcox or any other type of boiler is fitted. The entrance to the oval flue tube is of good area, and the corners should be well protected by shaped firebricks without the least impediment in the chimney draught.

The large number of cross-tubes in the main flue of this boiler absorb practically all the useful heat from the gaseous current so thoroughly that there is no need, under ordinary circumstances, of checking the chimney draught at the exit end to prevent useful heat escaping through the chimney, as is necessary with most boilers. If the furnace exit is of the correct practical minimum area, and the whole furnace of proper construction, there is no necessity for bottom and side flues, for under these circumstances the benefit accruing from the bottom and side flues is so small as to be negligible in practice.

When cleaning the fire grate or

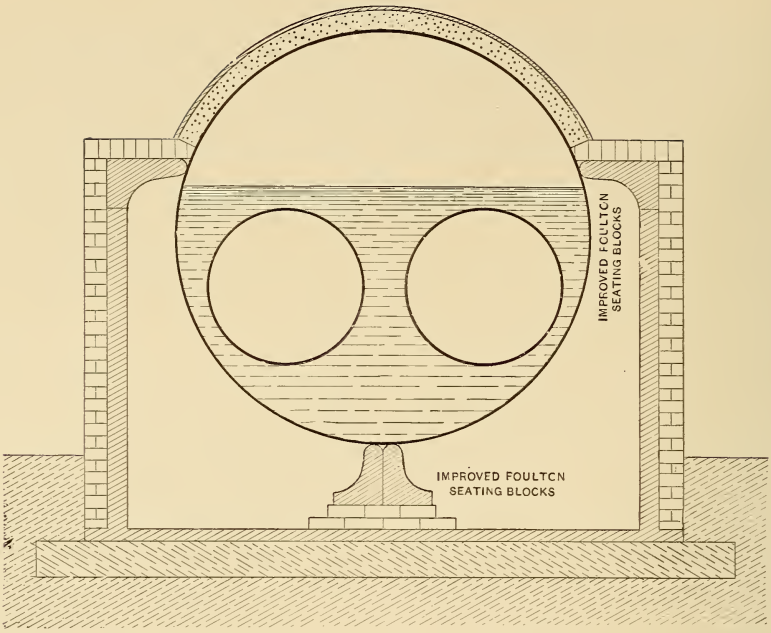


FIG. 5.—ARRANGEMENT OF BRICKWORK FLUES FOR A LANCASHIRE BOILER FIRED BY A REVERBERATORY FURNACE

cooling the furnace, it is advisable to partly lower the chimney damper in order to prevent cold air from passing too freely through the boiler. If the shell is of good diameter relatively to the flue tube, the water level may be easily maintained during the periods of high and low temperature of the furnace. The Galloway boiler is so well designed and constructed that it is practically unexplodable if short of water and overheated; the flue tube may collapse, but no further damage will occur.

If the Galloway boiler is worked and managed with one-half the care and skill employed in its design and manufacture, it will serve many years without any practical diminution of its efficiency and with the need of very little attention in the way of repairs.

THE LANCASHIRE BOILER

Although not by any means as suitable as the Galloway boiler or the Cornish boiler for working in conjunction with reverberatory furnaces, the Lancashire boiler is often employed for this purpose, with fairly good results when not worked too hard. Unlike the Galloway boiler, the Lancashire boiler is double-flued, thus necessitating the splitting up of the furnace gases into two portions. The entrances into the main flues should be protected by shaped firebricks, as in the case of the Galloway boiler.

The heat absorption of the main flues of the Lancashire boiler not being quite as thorough as in the case of the Galloway boiler, the brickwork flues cannot be so easily dispensed with. It is not necessary, however, to have both bottom and side flues, no advantage whatever being gained by allowing the heat current to travel the full length of the boiler more than twice, when treated by furnace gases. In other words, when heated by the waste heat of reverberatory or similar furnaces, the heat current should leave the boiler on its way to the chimney at the same end at which it enters, after

having twice traveled the full length of the boiler. Fig. 5 shows a good practical arrangement of brickwork flues for a Lancashire, or any other type of double-flued boiler, heated with furnace gases. If the efficiency and economic working of the boiler are to be maintained, it is essential that these flues be kept quite clean. They should be swept out at least once in every three weeks, and if possible every fortnight. If the boiler is not worked too hard, or beyond a pressure of, say, 50 to 70 pounds per square inch, these flues may be dispensed with, provided the draught at the exit end of the boiler is judiciously checked.

If they are dispensed with, rings of firebrick work should be built at the exit ends of the two main flues in order to reduce the area, and so cause the heat to linger in these flues long enough to impart the greater portion of its useful heat to the boiler. The sum area of the two flues at the exit end should be as nearly as possible equal to the area of the furnace-flue exit,—slightly less if possible. Experience and careful observation will soon enable the best area of boiler-flue exit, compatible with the conditions of working, to be found. If possible, however, it is much more advantageous to employ the brickwork flues, better circulation of the water being effected, with consequent increased steaming. In arranging brickwork flues, it should be borne in mind that as little as possible of the brickwork should be in contact with the boiler. Each square foot of brickwork in actual contact with the boiler plates represents a square foot of heating surface lost.

As in all other boilers, the water in the Lancashire boiler should be kept clean by frequent and regular blowing down,—twice a day if possible. The boiler should never be fed with cold water while at work. If worked under the conditions, and given the same week-end treatment as the Galloway boiler, the Lancashire boiler will go through a long and satisfactory period of service.

THE CORNISH BOILER

The Cornish boiler, which differs from the Lancashire boiler in that it possesses only one main flue tube instead of two, is well suited for attachment to a reverberatory furnace. It is cheaper than the Galloway and Lancashire boilers but, like these, can be made of suitable size and length for any furnace.

It is a safe, simple, easily cleaned boiler, and admits of the maintenance of a steady water level. As in the Galloway boiler, the entrance to the main flue tube requires protection by shaped firebricks. The flue tube is generally of large diameter, and the heating surface thus provided should be fully utilized by making the heat current fill the tube under ordinary conditions. This may be done and the best steaming results obtained by building a ring of firebricks in the exit end of the boiler, and on the bottom of this ring building a wall until the area of the remaining aperture is only 0.08 to 0.09 of the furnace fire grate area. This will give a maximum efficient result and obviate the necessity of bottom and side flues if the furnace exit flue is of the proper minimum area, viz., 0.10 of the fire grate area.

The Cornish boiler requires the same blowing down as the Lancashire and Galloway boilers, and also the same week-end treatment of changing two-thirds of the water, leaving nearly full for cooling, emptying, swilling out, and refilling with fresh clean water for the ensuing week's work. The damper should be partly lowered when cleaning the fire grate or cooling the furnace, in order to minimize the amount of cold air passing through the boiler.

THE RASTRICK BOILER

In very few treatises on steam boilers does one find mention of the Rastrick boiler. Though now somewhat out of date, this boiler, which is

of the vertical type, is used extensively in Great Britain, in the Midlands, especially in Staffordshire, and also in a few places in Lancashire. It is essentially an ironworks boiler, and is generally heated by the waste heat of two reverberatory or puddling furnaces.

A vertical section of this boiler is shown in Fig. 6, the course of the furnace gases being indicated by arrow heads. The gases, entering the brickwork flues *bb* of the boiler, through the furnace exits *aa*, ascend upwards and strike the lower arches of firebrick work *cc*. Impeded by these arches, they find their way up the outer sides of the dashwalls or

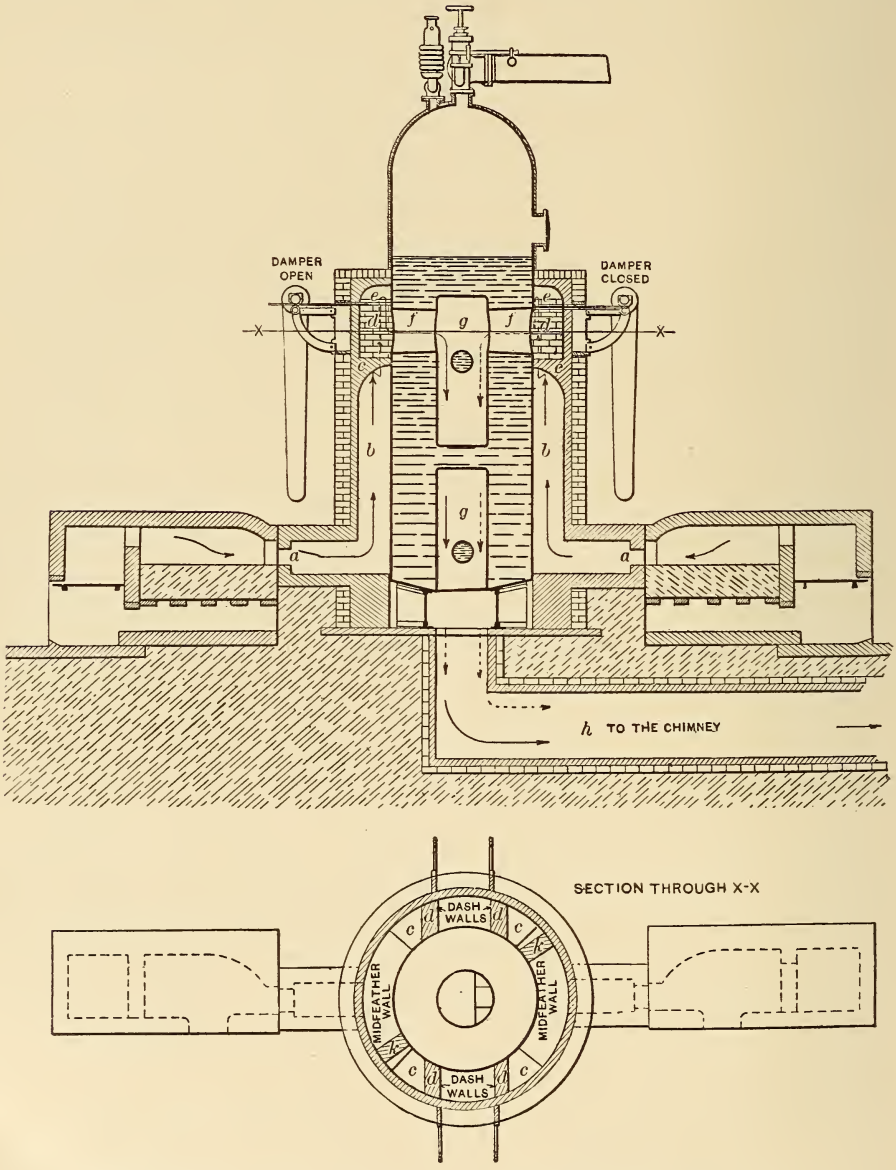


FIG. 6.—SECTIONAL PLAN AND ELEVATION OF A RASTRICK BOILER, FIRED BY TWO REVERBERATORY FURNACES

"bafflers" *dd*, and strike the top of the dampers *ee*. If the dampers are drawn, the gases at once enter the branch flue tubes *ff*, descend through the vertical flue tube *g*, and then, having imparted to the boiler as much of their useful heat as can be conveniently extracted, make their way through the underground flue *N* to the chimney.

The separate gases from each furnace do not mix together in the external flues *bb*, being kept entirely apart by two brickwork walls *kk*, known as "midfeather walls." They combine with each other, however, at the top of the vertical flue tube *g*, inside the boiler, and descend together on their way to the chimney. The midfeather walls divide the external flue into two equal parts. The flue gases, it will be observed, diffuse well around the outside of the boiler before entering the internal flues. After having passed through the apertures provided by the opening of the dampers, they are prevented from again diffusing around the boiler by the brickwork arches and the bafflers.

Boilers of the Rastrick type are often subject to severe punishment, and if they are to be preserved and their efficiency maintained they require the most careful supervision. They should never be left in the hands of incompetent or inexperienced workmen, although, unfortunately, this is sometimes the case. If the Rastrick boiler is not carefully worked and properly supervised, its lifetime will not be long; neither will it work satisfactorily.

It often happens that one of the furnaces to which this boiler is attached is not worked for a time, leaving the boiler to be heated by only one furnace. This should be avoided as far as possible, the unequal heating due to this cause doing much to assist the deterioration of the boiler. If it is found necessary to use only one furnace for any considerable time, the entrance into the external flue from the furnace not required should be bricked up and the midfeather walls removed to enable the heat current from the one furnace to course freely round the entire boiler, and so cause the boiler to be heated as uniformly as possible.

The water in the Rastrick boiler should be blown down about 7 inches at the end of every twelve hours' work. Both the internal and external flues should be thoroughly cleaned every fortnight.

Surrounded as it generally is by red-hot brickwork, the Rastrick boiler should under no circumstances be left empty for cooling.

THE VERTICAL CHIMNEY FLUE TUBE BOILER

This boiler, like the Rastrick boiler, is rarely mentioned in steam boiler literature. It is generally about 27 feet high by 6 feet in diameter, with a chimney flue tube which contains several cross-tubes passing upwards through the center. This flue, which should be about half the diameter of the boiler, aided by the cross-tubes, extracts heat from the furnace gases passing through it.

All the heat, however, is by no means extracted from the gases during their passage through the chimney flue, and consequently the damper at the top of the chimney should be checked to the lowest practicable limit. The upper and lower portions of the chimney flue tube should be protected by firebrick work, as shown in Fig. 7, in addition to which the boiler should be well covered externally to prevent radiation. This boiler, which should always be of the very best materials and workmanship, should be worked with a moderate column of water and a good steam space, the water being always kept clean. Every six hours, while at work, the water should be raised to the top of the gauge glass and blown down again to the working level. The boiler should be thoroughly cleaned out every week.

THE FEEDING OF BOILERS

One of the most important matters

in steam-boiler management is that suitable arrangements be made for good, continuous feeding. The feed water should always be as nearly as practicable at the temperature of the steam when fed into the boiler. This is generally effected by passing the feed water through an economizer after being pumped through a hot well. In cases where economizers are not worked in conjunction with externally fired boilers, the feed water should be raised to as high a temperature as possible by passing it through a hot well before being pumped into the boiler. When the boiler is fed by an injector, the water is raised to a fairly satisfactory temperature by the steam which forces it into the boiler.

In conclusion, it should always be borne in mind that, however high the quality of a boiler, its efficiency is soon impaired by improper or careless management. Nothing is so conducive to successful working as good, rational management and careful supervision. Frequent and regular blowing down; leaving the boiler nearly full of water for cooling; never under any circumstances allowing cold water to enter the boiler while at work; hot continuous feeding and the maintenance of a steady water level; all these are details which, properly carried out, tend much to insure the successful, efficient, and economic working of all classes of steam boilers.

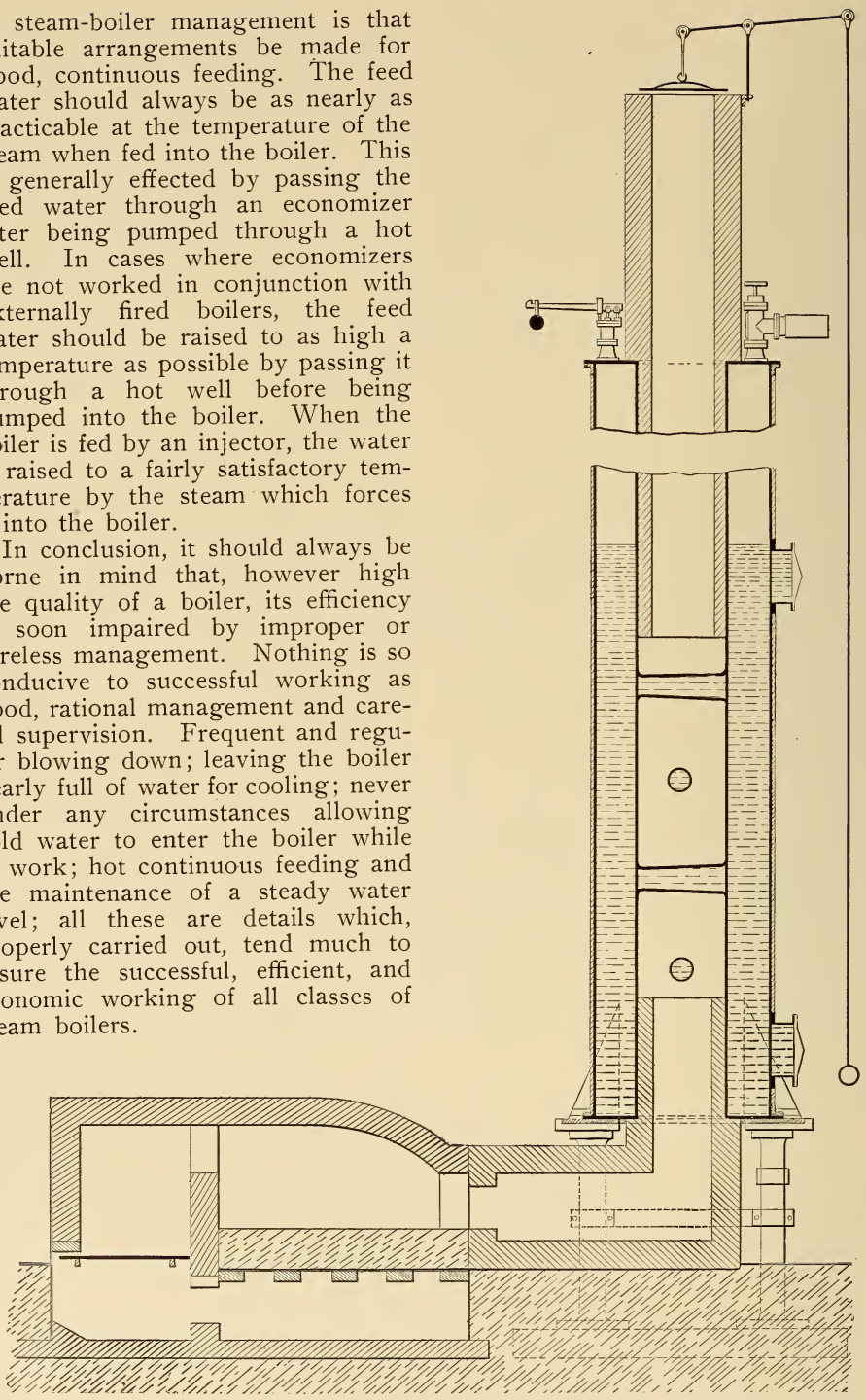


FIG. 7.—VERTICAL CHIMNEY FLUE BOILER

MODERN BRITISH HIGH-SPEED STEAM ENGINES

By Leo H. Jackson

PART II.—EXAMPLES OF CURRENT PRACTICE

Part I, in the August Number, was devoted to a Discussion of the Typical Features of Engines of this Class

THE BELLISS & MORCOM ENGINE

THE pioneers of forced lubrication, Messrs. Belliss & Morcom, Ltd., of Birmingham, having originated the system in 1890, prefer to style their engines "quick-revolution" rather than "high-speed" engines. There is a distinction between the two terms which is worth noting, as owing to the very short stroke of piston, the advantages of a high rate of rotation are obtained without excessive piston speed.

For all that, the name of "high-speed" engines has long been associated with this type, and the more correct term has failed to secure popular recognition. Not so, however, with the engine itself, by whichever name it may be known, for Messrs. Belliss publish a long list of municipal and public lighting and power stations in every part of the world where their engines are in use, figuring up something like half a million horse-power. For instance, the very fine 2000 B. H. P. triple-expansion engine, shown in Fig. 1, is installed in the City of Leeds electric light station, similar engines being supplied, or in hand, for Hackney, Dublin, Central Electric Supply Company, Ltd., London, Birmingham, etc.

This size of engine is designed to develop 2000 brake horse-power as a normal full load at a speed of 200 revolutions per minute, with a steam pressure of 170 pounds, condensing. It has also to exert an overload of 10 per cent. for short periods of time, and on test a maximum load of 1887 kilowatts, say 2700 B. H. P., was actually carried. The cylinders are 23, 35, and 55 inches in diameter, with a stroke of 30 inches, giving a piston speed of 1000 feet per minute and working upon three cranks set 120 degrees apart. As usual in Messrs. Belliss & Morcom's engines, of whatever size, piston valves only are used, their experience being that by actual test, piston valves are not only better for smooth running and efficiency, but also for economical performance. The particular engine shown is coupled to a two-phase alternating-current generator, made by the Electric Construction Company, Ltd., of Wolverhampton, with a designed output of 1400 to 1500 kilowatts. The Corporation of Leeds showed their appreciation of this unit by ordering a duplicate set, which is now at work.

The internal arrangement of this engine is shown by the sectional view, Fig. 2, from which we note that each cylinder has its own separate piston-valve chamber, differing in this respect from their two-crank compound engine in which, as is well known, Messrs. Belliss & Morcom make use of a single valve chamber containing a combined high and low-pressure piston valve. The cranks are not fitted with counter-balances, the weights of both pistons with their appendages being equalized. From the results, which we shall come to presently, showing little or no wear after years of running, we are forced to the conclusion that crank counter-balances are a superfluity, and it is

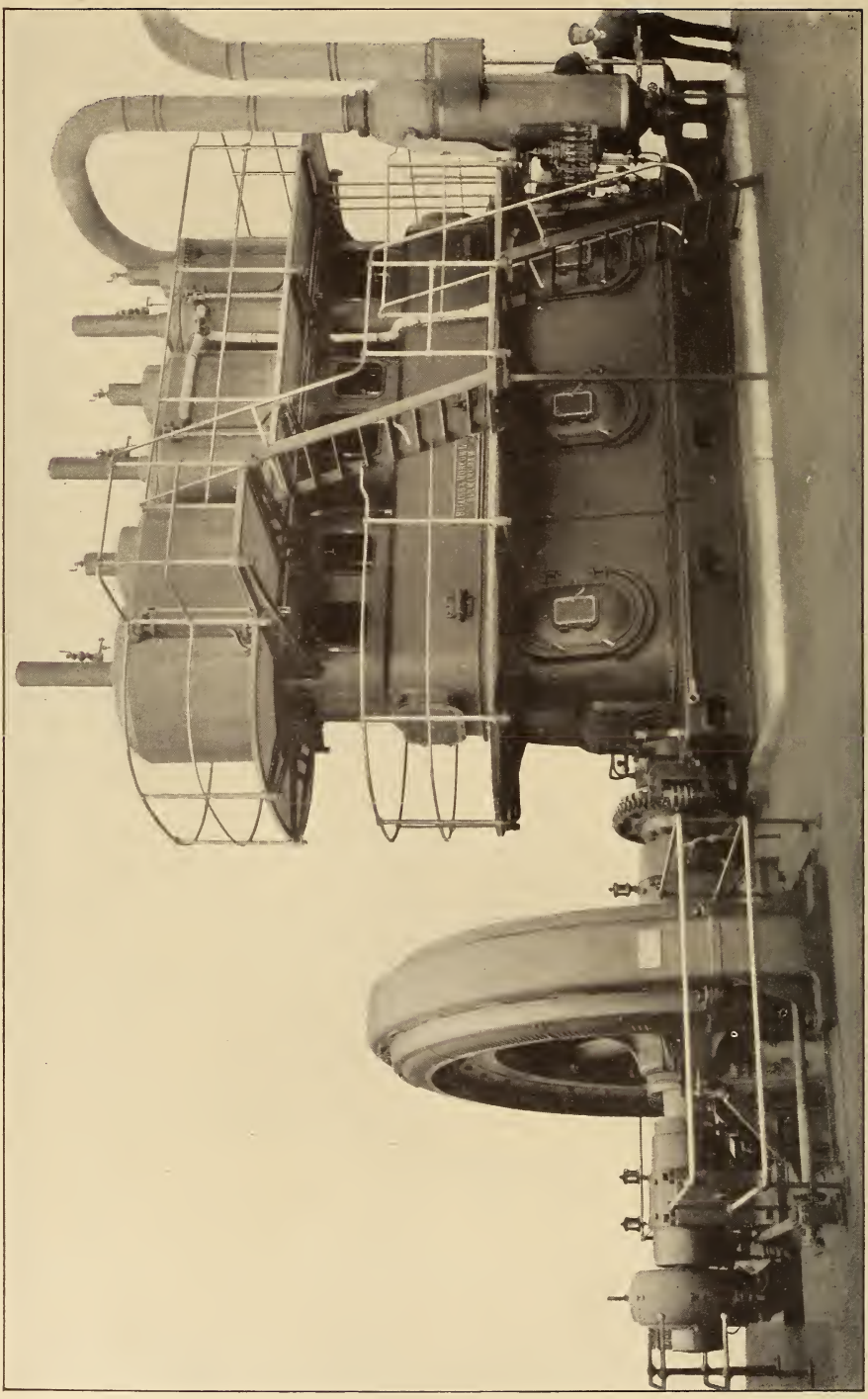
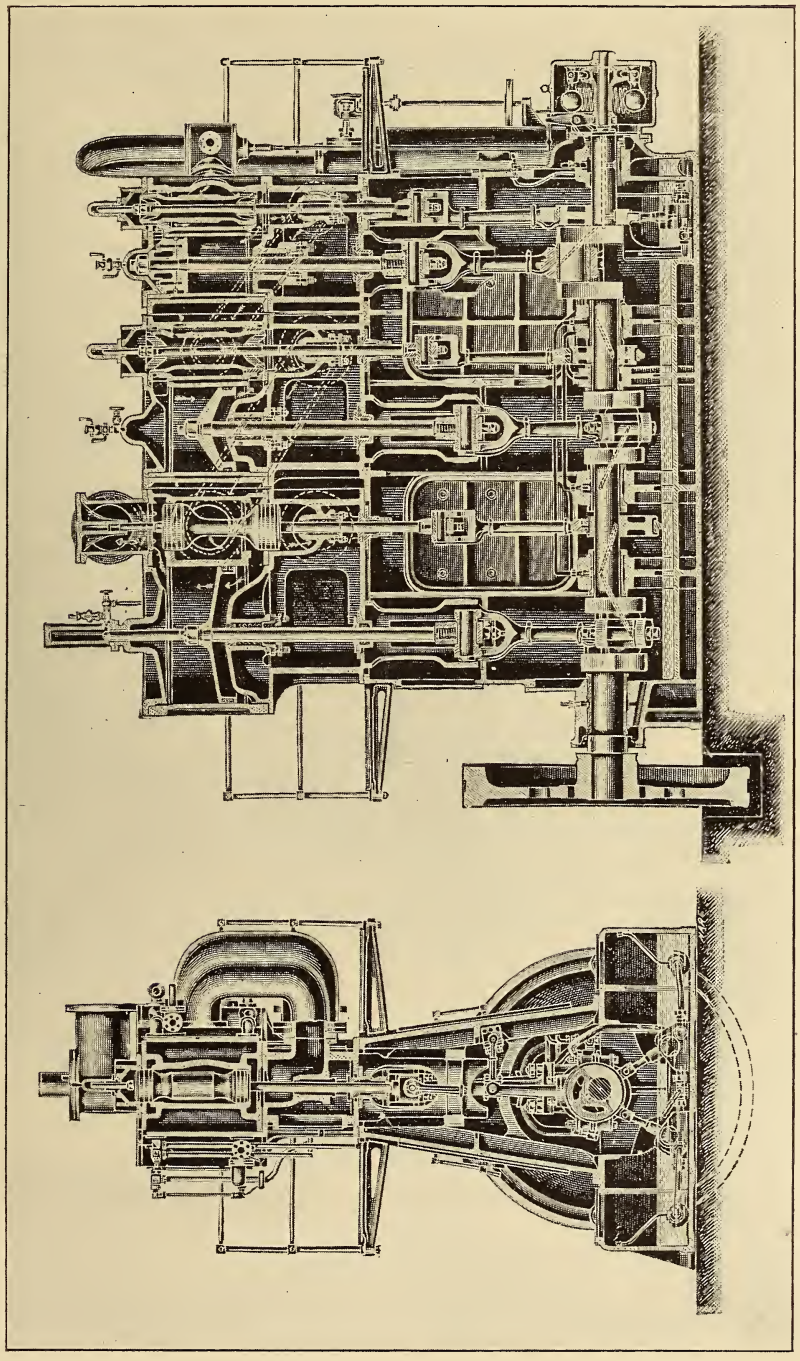


FIG. 1.—A 2000-B. H. P. TRIPLE-EXPANSION ENGINE BUILT BY MESSRS. BELLISS & MORCOM, LTD., BIRMINGHAM, DIRECT CONNECTED TO A TWO-PHASE ALTERNATOR BUILT BY THE ELECTRIC CONSTRUCTION CO., LTD., WOLVERHAMPTON



[FIG. 2.—VERTICAL SECTIONS OF THE TRIPLE-EXPANSION ENGINE (TYPE T) BUILT BY MESSRS. BELLISS & MORCOM, LTD.

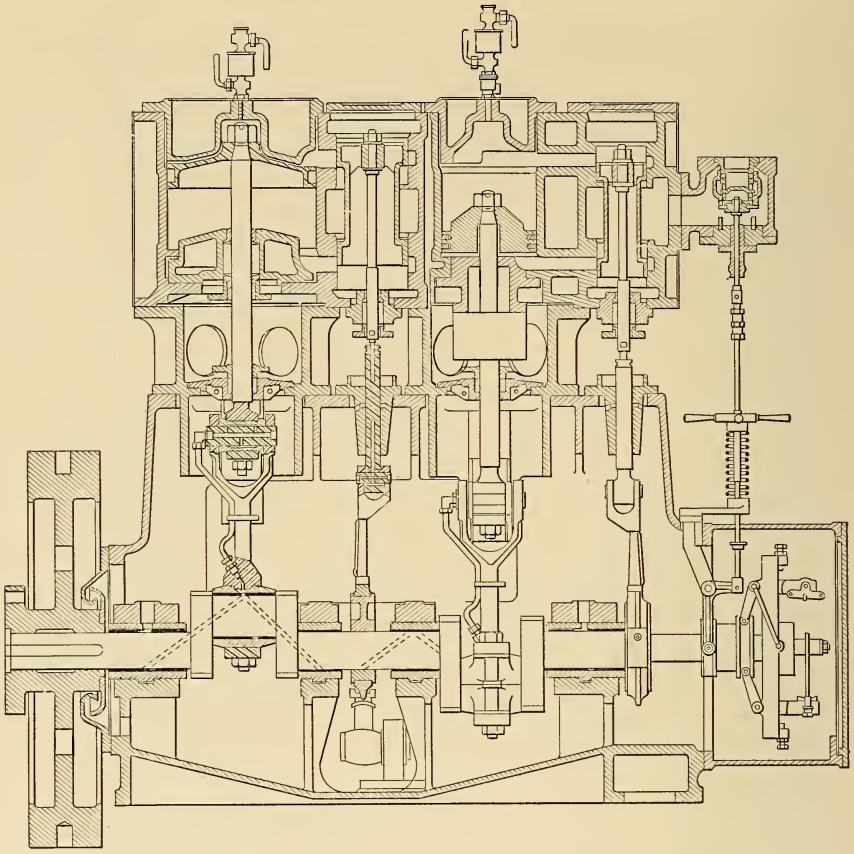


FIG. 3.—COMPOUND TWO-CRANK ENGINE BUILT BY MESSRS. BROWETT, LINDLEY & CO., LTD., PATRICROFT, MANCHESTER

difficult to find a reason for their retention. We know of at least one case where the breakage of the steel strap or band, by which the weight was secured to the crank cheek, resulted in the practical destruction of the engine. Messrs. Belliss mention also that they now have discarded the "separator," an adjunct shown in almost every one of our illustrations as a vertical drum or cylinder designed to entrap the water coming over with the steam.

We bow to Messrs. Belliss' wide experience, which has led them to question the utility of this appliance, but except in cases where the steam is "dried" or slightly superheated, or the connection to the boiler is very direct, of ample area, and efficiently drained, we must confess that we should take advantage of the firm's offer to fit separators "whenever specified."

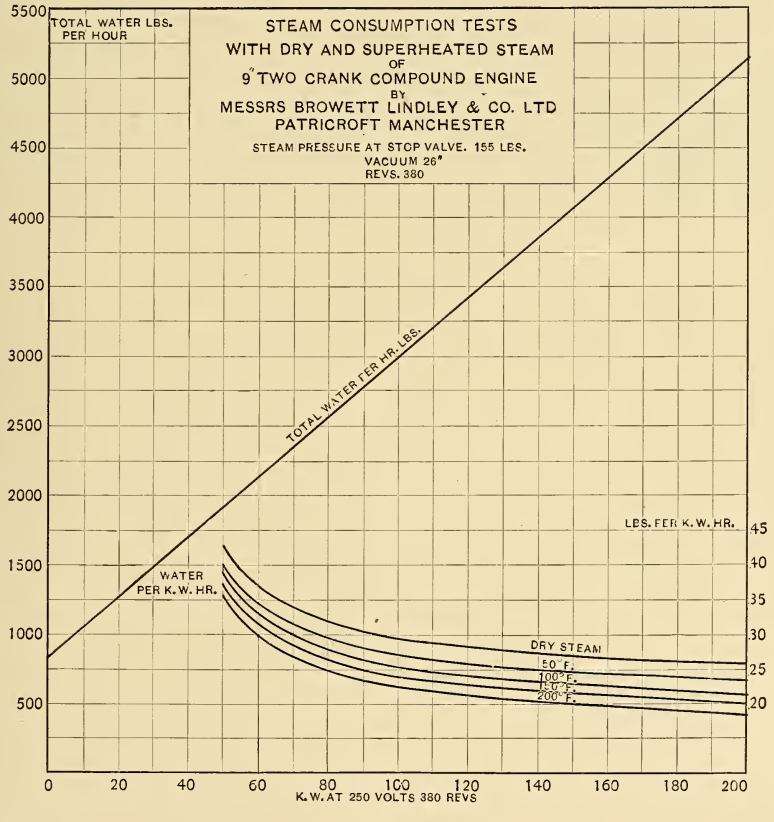
Steady running and close governing are qualities of immense importance in electric power or traction work, where the entire load is liable to be thrown off at any moment, followed, perhaps, instantly by its reimposition. Needless to say, the strain upon the engine is very severe, and comparable only to the work upon a rolling-mill engine, where for a few seconds practically the whole power of the engine, assisted by the resident energy in the massive fly-wheel, is absorbed in one great effort, to be as suddenly released. But there is this difference

in the conditions,—regularity in speed, or rather in rate of revolution, is not the prevailing characteristic in rolling-mill engines. In electric traction work, on the contrary, it is of the highest importance. This is the demand.

Let us see how it is met. "We are prepared," say Messrs. Belliss & Morcom, "to guarantee that the variation of speed from the normal shall not exceed 1 per cent. permanent, and 2 per cent. momentary with the whole load suddenly removed, providing the requirement is stated in the customers' inquiry, so that the slight additional cost involved may be allowed for.

THE BROWETT, LINDLEY & CO. ENGINE

The two-crank compound and three-crank triple-expansion engines of Messrs. Browett, Lindley & Co., Ltd., of Patricroft, Manchester, are shown in Figs. 3, 5 and 6, together with a diagram, Fig. 4, giving the results of a steam-consumption test from a 9-inch compound using dry saturated steam* of 155 pounds pressure, and from the same engine with steam superheated successively 50, 100, 150 and 200 degrees F. above normal temperature. Independently of the excellent performance tabulated, this chart is worthy of study as an authentic record of parallel performances with steam at varying temperatures. Although the figures given are from an engine of very moderate dimensions, it will be noticed that they compare very



F.G. 4

* An apparent, but not a real, contradiction; the term ordinarily used to indicate steam at normal temperature, but free from entrained water.

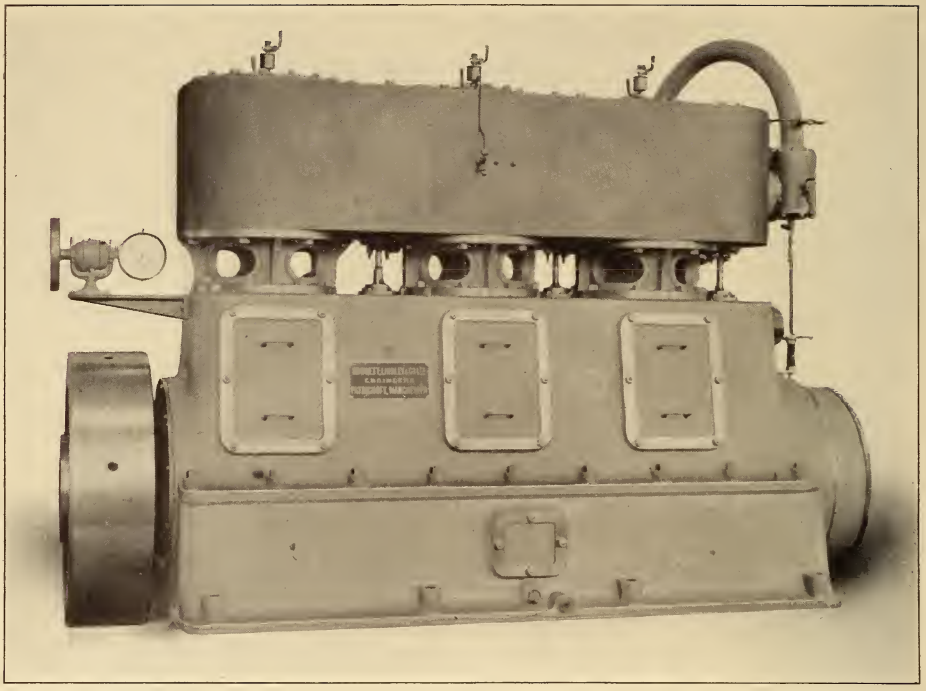


FIG. 5.—A THREE-CRANK TRIPLE-EXPANSION ENGINE BUILT BY MESSRS. BROWETT, LINDLEY & CO., LTD.

favourably with recent published results from steam turbines. In fact (say Messrs. Browett, Lindley & Co.), it may be taken that, as a rule, a purposely designed reciprocating engine will show a better result in steam consumption than a turbine up to full load, while below three-quarter load the result is very much in favour of the former.

Turning to the construction of the engine, it will be seen that the compound engine is made with separate cylinders, and throughout practically on the lines of our typical engine, and that being so, it will be found fully described in last month's section of this article, the only special feature being that the high-pressure piston-rod is fitted with metallic packing. The triple-expansion engine also does not greatly differ from what we may call the standard design, excepting that the casing is comparatively much lower, and the conical distance-pieces, containing the guide-trunks, correspondingly of greater height. The high-pressure and intermediate cylinders are fitted with piston-valves, and the low-pressure cylinder has a balanced slide-valve. Each cylinder stands independently with its own valve-chamber or steam-chest. There are two valveless oil-pumps, both worked from the intermediate eccentric-strap.

As an instance of the care with which the details are worked out, it will be observed that even the joints of the bell-crank levers forming the governor-arms, partake of the advantages of forced lubrication.

The triple-expansion engine shown has cylinders 20, 30 and 46 inches in diameter by 30 inches stroke, and runs at 200 revolutions—1000 feet of piston speed—per minute, a pace which it would be impossible to maintain with certainty for any length of time without the use of an efficient system of forced lubrication.

THE SCOTT & MOUNTAIN ENGINE

Messrs. Ernest Scott & Mountain, Ltd., of Newcastle-on-Tyne, are makers on a large scale of high-speed forced lubrication engines. Their principal types are two-crank and three-crank compound engines. Generally speaking, in the two-crank engines, they are firm adherents of the plan of casting the two cylinders in one piece, having a central chamber or steam-chest, with a renewable liner enclosing two superposed hollow piston-valves on the same spindle, and driven by one eccentric.

This arrangement has much to commend it in the way of simplicity and compactness, and the writer is quite willing to believe that in practice no harm results either indirectly by the transfer of heat, or directly by leakage. Both of these hollow valves are in fact channels or passages, through which steam at receiver pressure is passing at a high velocity, and, in theory certainly, heat would be abstracted from the belt of high-pressure steam surrounding the lower valve, and imparted to the similar belt of exhaust steam encircling the upper one.

However, the plain fact that engines on these lines are made by two or three of the principal manufacturers, who have built up a new trade, and achieved an enviable reputation for economy, goes far to disarm outside criticism. Messrs. Scott & Mountain do not forge their cross-heads in one piece with the piston-rod, but cotter it in with a tap, and provide a forcing-nut for drawing the rod out of the cross-head.

From the point of view of con-

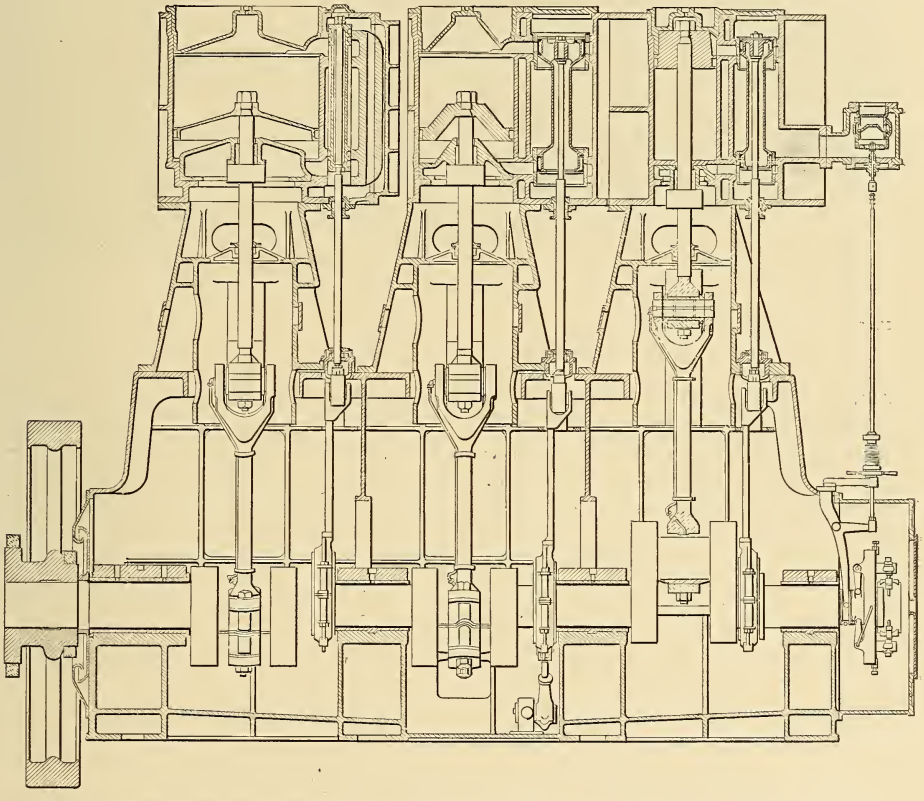


FIG. 6.—THREE-CRANK TRIPLE-EXPANSION ENGINE BUILT BY MESSRS. BROWETT, LINDLEY & CO., LTD.

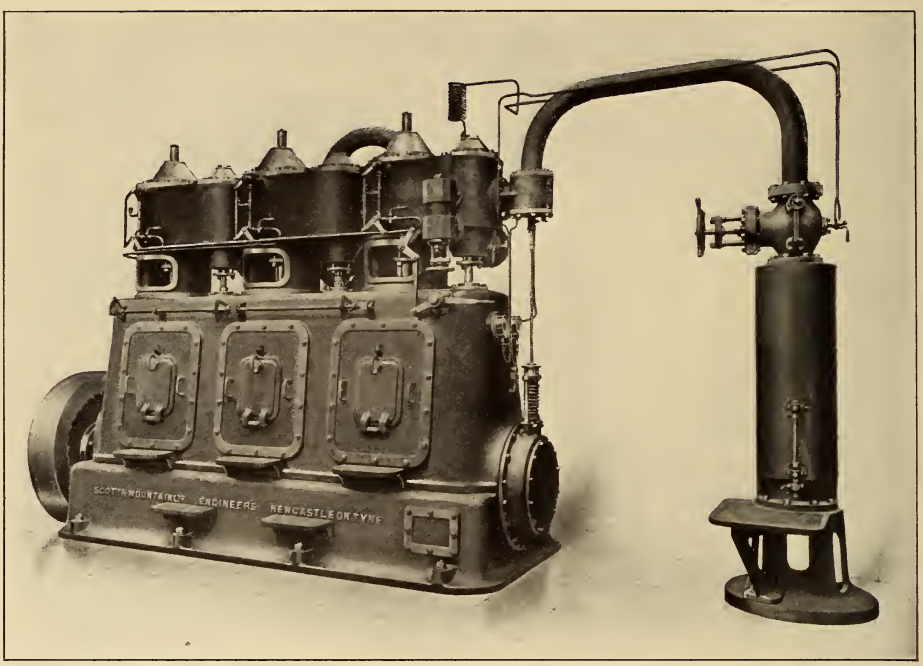


FIG. 7.—A THREE-CRANK COMPOUND ENCLOSED ENGINE BUILT BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE

venience in taking apart, this is to be commended; there are, however, four parts in place of one, with the possibility—a bare possibility—of their working loose some day.

The throttle-valve, actuated by a governor of the ordinary tension-spring type, consists of two plain rings working in a double-ported liner. The writer has already commented on the simplicity of their excellent form of valve, which, though not adjustable for taking up wear, is easily and cheaply renewed. The makers state that it easily controls the engine within 5 per cent. between full load and no load. The two-crank compound engines are made in seven sizes, from 5 to 12 inches stroke, and with two ratios of cylinders, viz.: 3 to 1 for pressures between 120 pounds and 160 pounds, and 2.4 to 1 for pressures ranging from 80 pounds to 110 pounds, with piston speeds up to 700 feet per minute.

Messrs. Scott & Mountain are to be commended for the very full information they give in their circulars of these engines, as to dimensions, prices, weights, sizes of steam and exhaust pipes and space occupied, together with the effective horse-power developed by each size at four different speeds, and with five different steam pressures, thus enabling a prospective purchaser to put his hand in a moment upon the size of engine adapted to his requirements—a result generally obtained only after the interchange of several letters.

Their three-crank compound engines are made also in seven sizes, from 8 to 14 inches stroke, with a cylinder ratio of 3 to 1 for 120 to 160 pounds steam, and of $2\frac{1}{2}$ to 1 for 80 to 110 pounds steam.

For any one of four speeds up to 750 feet of piston speed per minute, the brake horse-powers at five different pressures are given. For example, one can have 1350 effective horse-power from a

$$\frac{26 + 32 + 32}{14}$$

engine, running at 320 revolutions per minute, with 160 pounds initial steam pressure, or just over 1550 H. P., with the same engine condensing, within a space of 17 feet, 6 inches by 7 feet, 6 inches by 12 feet high.

The size of steam-pipe required is 10 inches, and the exhaust pipe 16 inches. These engines have an advantage over the two-crank, two-cylinder compounds in that there being two low-pressure cylinders, each of half the normal capacity, the turning moment, being divided over three cranks set at 120 degrees apart, is almost uniform throughout the revolution. These engines are thus well adapted for generator sets in city installations, where earth-vibrations, set up by imperfectly-balanced reciprocating engines, and sometimes communicated through considerable distances, are apt to induce claims for compensation as unexpected as they are unwelcome.

The three cylinders, each with its own valve-chamber, and piston-valve and eccentric, are entirely independent of, and separate from, one another, and the writer must confess that he prefers this arrangement. Altogether, Messrs. Scott & Mountain's three-crank compound engine is of admirable design, and it is evident from an inspection of the drawings that the details are thoroughly well worked out.

This firm, it should be noted, does not employ counter-balance weights in either their two or three-crank engines, which, with the exceptions noted, conform very closely in ar-

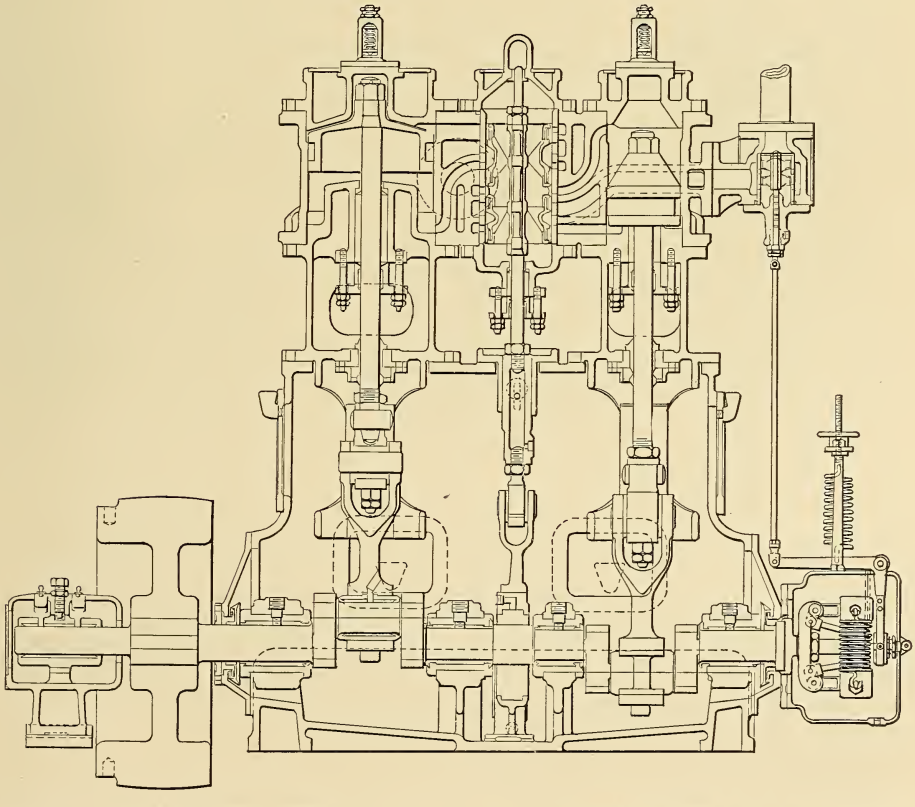


FIG. 8.—TWO-CRANK COMPOUND CENTRAL-VALVE ENGINE BUILT BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD

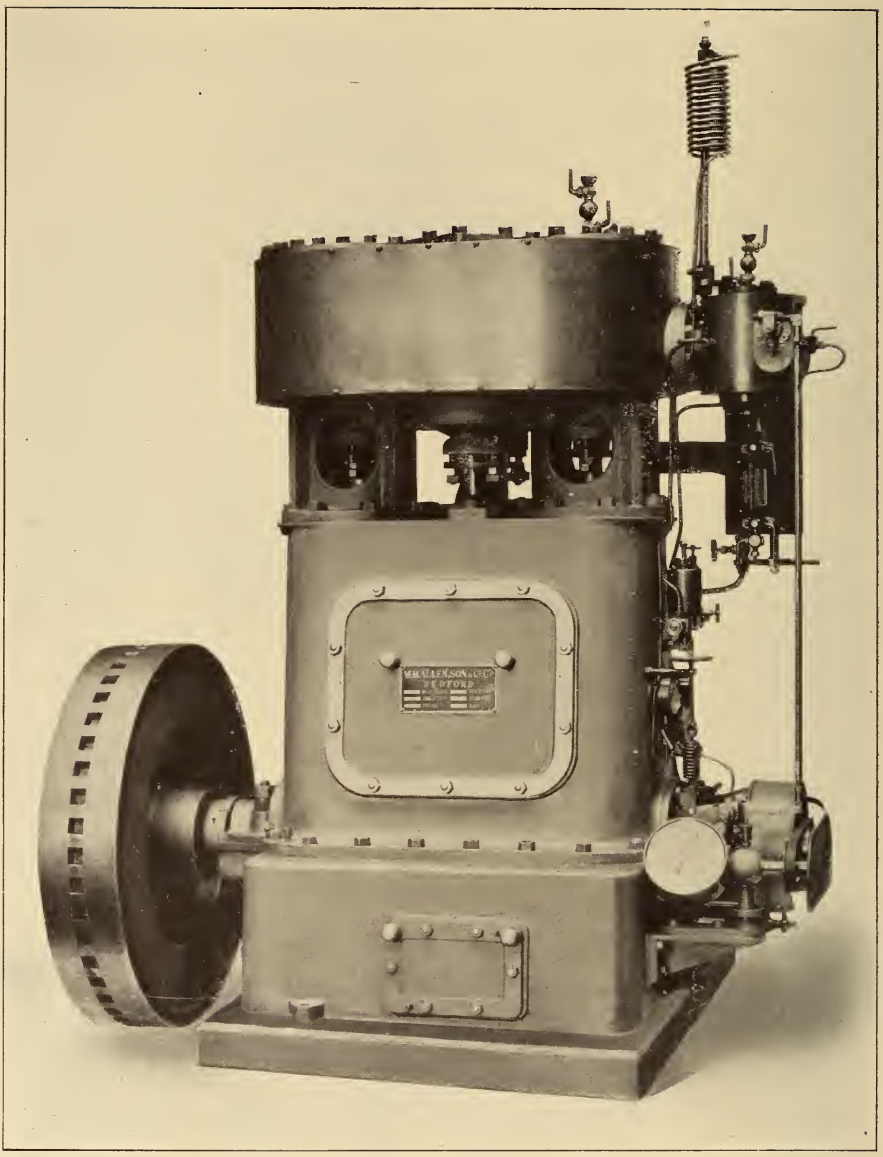


FIG. 9.—A TWO-CYLINDER, TWO-CRANK COMPOUND ENGINE WITH CYLINDERS AND VALVE CHESTS IN ONE PIECE. BUILT BY MESSRS. W. H. ALLEN, SON & CO., LTD., BEDFORD

rangement to the typical engine described at the beginning of this article.

THE ALLEN, SON & CO. ENGINE

Messrs. W. H. Allen, Son & Co., Ltd., of Bedford, commenced the manufacture of this class of engine in 1894, on opening their new works at Bedford. Their standard types comprise single-cylinder, single-crank engines; two-cylinder, two-crank compound engines, with cylinders and valve chests all cast in one piece, also of the same class, with cylinders separated; three-cylinder, three-crank compound, and three-cylinder, three-crank, triple-expansion engines. Rowans' rings are

used in the pistons, but the piston-valves are all of the plain solid pattern, without rings, and are easily renewable; all receive steam at the center, exhausting at the outer edges, thus avoiding the necessity of having full steam pressure at the glands. (See Figs. 9, 10 and 11.)

In Messrs. Allens' smaller two-crank engine the cylinders are cast together, the high and low-pressure valve-chests, each with its own separate valve, being both situated between the cylinders, the high-pressure in front and the low-pressure at the back. The two valve spindles are connected by a cross-head, and are driven by a single eccentric.

The separate cylinder compound engine for central-station work is made up to 450 I. H. P. at 350 revolutions per minute. Test figures, taken from the official trials of one of these engines record the following very satisfactory results:—

Main steam pressure	150 lbs
Throttled steam pressure	139 lbs.
Mean I. H. P.	386 lbs.
Mean B. H. P.	350 lbs.
Revolutions per minute	375
Vacuum at engine exhaust	26 ins.
Water per I. H. P. hour	15.5 lbs.
Water per B. H. P. per hour	17.1 lbs.
Efficiency	91 per cent.
Normal full-load speed	375 revs.
Momentary rise on removal of full load	390 revs.
Speed when running light	384 revs.
Maximum variation (momentary)	4 per cent.
Variation per cent. (steady)	2.4 per cent.

In connection with this it is interesting to note that the governor is of the ordinary centrifugal type, operating a double-beat throttle-valve by a rocking lever, and provided with hand adjustment by means

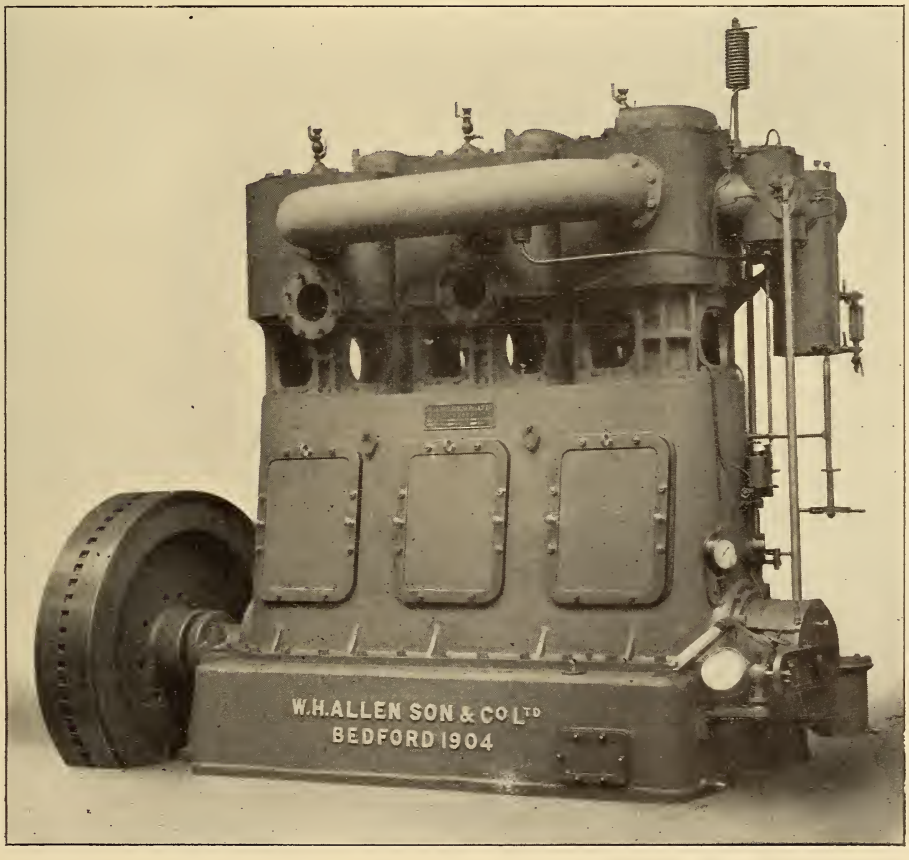


FIG. 10.—A THREE-CYLINDER, THREE-CRANK COMPOUND ENGINE BUILT BY MESSRS. W. H. ALLEN, SON & CO., LTD.

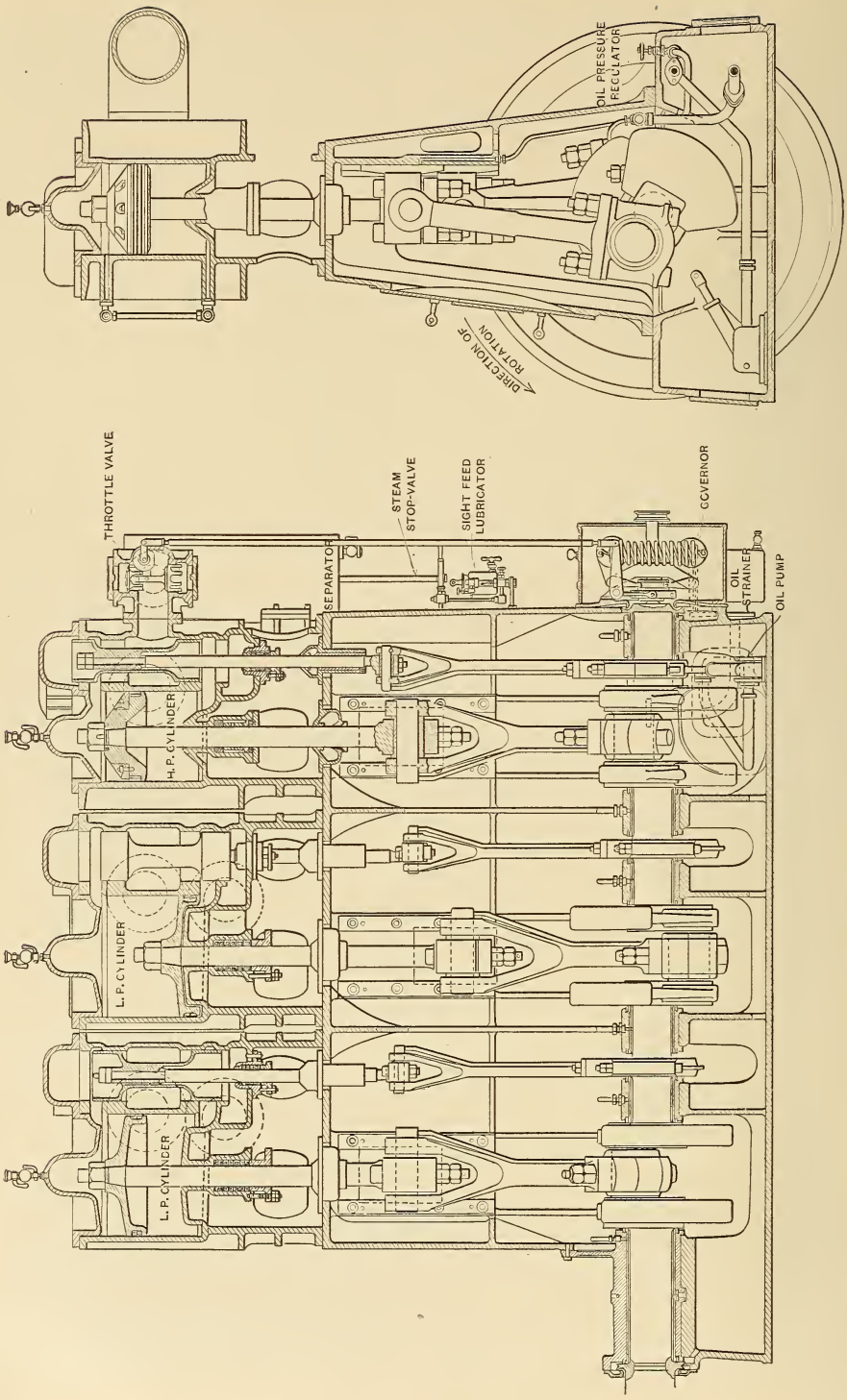


FIG. 11.—THREE-CYLINDER THREE-CRANK ENGINE BUILT BY MESSRS. W. H. ALLEN, SON & CO., LTD.

of which the speed may be varied.

In the three-crank compound class there are two low-pressure cylinders, giving an exceedingly even turning moment, and it is a most serviceable type for central-station work, for steam pressures from 125 pounds to 175 pounds per square inch. An official test of one of these engines at Messrs. Allen's works gave the following results:—

Main steam pressure	150 lbs.
Throttled steam pressure	120 lbs.
Mean I. H. P.	594 lbs.
Mean B. H. P.	464 lbs.
Revolutions per minute	336
Vacuum at engine exhaust	26 ins.
Water per I. H. P. per hour	15.4 lbs.
Water per B. H. P. per hour	16.75 lbs.
Efficiency	92 per cent.
Normal full-load speed	350 revs.
Momentary rise on removal of full load	370 revs.
Speed when running light	360 revs.
Maximum variation (momentary)	5.7 per cent.
Variation per cent. (steady)	2.0 per cent.

Recent developments in the design of high-speed, forced lubrication engines are well illustrated in the Allen three-crank, triple-expansion engine, which has been designed throughout with a view to obtaining economical results over widely-varying conditions of load, when working with dry steam at 150 pounds pressure, and exhausting against a maximum absolute pressure of 4 inches of mercury, and to be further capable of developing an overload of 25 per cent. for periods of two hours at a time.

As in the case of the two and three-crank compound engines, the dimensions of the cylinders and the successive points of cut-off are so arranged as to produce an equal distribution of power between the cylinders, thereby ensuring an exceedingly even turning moment throughout the revolution. Also, the weights of the reciprocating parts on each crank are equalized in order to eliminate the resultant vertical and horizontal forces due to the inertia of the moving parts. In all Messrs. Allen's engines the cranks are counter-weighted by segmental-shaped weights, attached to the crank cheeks by straps.

The governor is so arranged that at overload, steam is bye-passed to the low-pressure cylinder by means of a compound double-beat throttle valve. In the case of two sets of these engines, built by Messrs. Allen to the order of the Fairfield Shipbuilding & Engineering Co., Ltd., of Govan, Glasgow, it was specified that the steady speed variation from no load to full load should not exceed 3 per cent., and that the momentary variation in speed, when the whole load was suddenly thrown off or on, should not exceed 10 per cent. On the official trial, however, the governing test showed a steady speed variation from no-load to full load of 1.9 per cent., and a momentary variation, when the full load was suddenly thrown off or on, of 5 per cent., thus being largely in advance of the specific conditions.

The mean results of the official trials of these engines, which had cylinders 13, 20, and 30 inches in diameter by 13 inches stroke, are appended thus:—

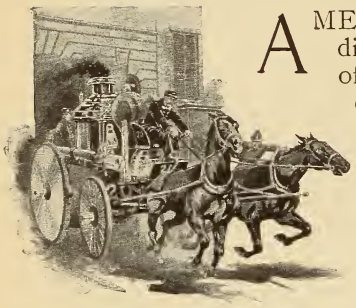
Main steam pressure	160 lbs.
Throttled steam pressure	143 lbs.
Mean I. H. P.	578 lbs.
Mean B. H. P.	540 lbs.
Mean revolutions per minute	330
Vacuum at engine exhaust	25.35 ins.
Water per I. H. P. per hour	14.2 lbs.
Water per B. H. P.	15.2 lbs.
Efficiency	93.5 per cent.

In Part III. of this article, to appear in the October number, several additional examples of current practice will be presented.

HIGH-PRESSURE SYSTEMS FOR CITY FIRE PROTECTION

FIRE LESSONS IN AMERICA

By Albert Blauvelt, Fire Protection Engineer



AMERICAN cities differ from those of most other countries in that the average height and combustible mass of their buildings are greater. There are also more frequent fires and more congested values; hence there is greater fire loss as compared to values. American cities, too, are generally credited with having the most highly organized and powerful fire departments in the world, and yet not one of these cities has thus far developed an economic fire protection system.

The above expression does not mean the degree of fire protection necessary to cope with everyday fires, because this need is fairly well taken care of in most cities. But this ordinarily successful protection for the larger cities is not sufficient to eliminate the chances of sweeping conflagrations, particularly in the great cities.

As sweeping conflagrations are very rare,—no conflagration great enough to seriously embarrass insurance capital having occurred since the Chicago fire of 1871,—it is manifest that the majority of taxpayers of any city will not be likely to wish to pay for providing against so remote a contingency, unless doing so will, at the same time, bring about some immediate or at least prospective saving in fire insurance rates. These, however, do not, as a rule, go lower until after losses are reduced.

Nevertheless, certain citizens of various cities recognize that a conflagration is by no means paid by insurance, and that even this insurance money must eventually be paid out in increased rates. Hence the direct and indirect cost of any conflagration all falls finally on the public. Furthermore, a few of the larger cities have now grown to have such great congested values that a conflagration would be quite capable of wrecking the trade and general interests of the city.

Passing over the contingency of a conflagration, it is of everyday interest that the average insurance rates of the larger American cities are proof of a relatively high fire waste, and the fact that specially protected isolated buildings show far less fire waste as compared to values, causes many city property-owners and allied interests to seek some way of escaping the fire tax due to being in a city,—some way to make the average city risk compare more favourably with the protected isolated risk—some way to get rid of danger from neighbours.

How, in protected cities, to approach the low fire cost of protected isolated risks, is something about which a variety of conflicting opinions is constantly being put forward, —some in favour of fireproof construction; some in favour of automatic sprinklers, or in favour of high-pressure pumps and mains; in favour of increased precautions against fire, or of increased fire departments.

At present a prominent subject of agitation for protection of large cities is the "high-pressure system." The expression "high-pressure system" is, in itself, exceedingly vague. Any system of city fire protection must use high pressure. Whether such a system can be made to reliably extinguish fires—not at too much expense, yet not too expensively late—is a question of differing engineering, political and financial complexity in every large city.

A few general characteristics of large American cities may safely be taken as fixed. The native carelessness and frequent fires, causing alarms (say 10 to 30 per day for a large city) can be counted on to continue for the present generation at least. The close grouping of buildings, the thin glass and pine window sashes lining the streets, and the occasional large buildings containing huge quantities of burnable contents are also features not likely to disappear soon.

The entire question of fire protection is one of expense. The cost of providing for immediate and intelligent application of water anywhere and everywhere for all incipient fires in a city would be prohibitive. For example, men with apparatus could not be stationed everywhere.

The cost of permitting fires to burn unchecked is well known to be prohibitive. Hence the problem of fire protection in cities is to make direct application of water on the fires which occur, and to do this, not at too much expense, nor, as already stated, too expensively late.

More or less well and ill-conceived high-pressure projects are being planned or are under discussion in New York, Chicago and Cleveland. Other cities, as Philadelphia, Boston and Providence, have actual installations called high-pressure systems, apparently so termed because originally installed with the thought of constant high pressure primarily for fire protection.

Other cities, again, as Cleveland, Detroit, and Milwaukee, have systems of independent street mains supplied by high pressure from fire boats, and so used only when needed for fire department use. Still other cities have high-pressure water, often from a practically inexhaustible gravity reservoir supply to a system of mains covering the entire city. Curiously enough, these very cities which are best off as to high-pressure systems, are not so advertised and do not get, and thus far do not deserve, much credit for the high pressure.

Nothing has impressed the writer so much from reading press notices of high-pressure systems, or from serving on preliminary work for the proposed high-pressure system for Chicago, or serving on the National Fire Protection Association Committee work on the general subject—as to note the wide range of assumptions, sometimes very unwarrantable, exhibited by city officials, firemen, editors, various types of insurance men, politicians, large taxpayers, and similar men—all of whom have necessarily considerable influence upon any municipal fire protection project. While there is no way of avoiding so many cooks for the broth, this paper is written in the hope that a review, largely of well-known facts, may assist even slightly to clear part of the existing confusion of views.

The purport of this article is largely in the direction of pointing out what not to believe, and of showing up a number of points which cannot be disposed of by lazy assumptions. It is needless to assume that fire department facilities have to be increased or improved at all, whether by a high-pressure system or by any other means, without first ascertaining whether the real danger is not resident in huge buildings, apparently innocent in themselves, yet plague spots in any city, because the mere size and mass of combustible in such buildings make them as uncertain of control by any fire department as a group of high frame buildings would be. In other words, the main ques-

tion may not refer to the fire department, but it may be for the police powers of the city to compel special protection of plague spots at the expense of the owners of them and not at public expense.

It certainly does not seem possible that the police powers of a city are exhausted after having provided that none but brick structures shall be erected within certain limits. Every large city contains buildings having no bad features except their mere area and the mass of combustible in them which places them beyond the sure control of any fire department operating with present-day facilities.

It is a question whether the police powers of a city should not be extended to compel big mercantile buildings, merely because big, to be arranged so that fire department service can be effective. Such a requirement would be just as reasonable as the one that a structure be built of brick instead of wooden framing, with the intent of making the building manageable by fire department facilities.

It will not do to assume that the fire department chief is an authority as to plans for more efficient fire protection. Some of these men are intelligent and progressive; yet there are others who apparently would dislike to lose the excitement and public display in action brought about by occasional big fires, or even regard it as a breach of etiquette for a fire to be controlled by other than time-honoured fire department methods.

Some of the best chiefs are to but a slight degree fire engineers, and yet have, and deserve, much repute as fire chiefs because they are strong executives and department disciplinarians. Still they do no more, and are not expected to do more, than make old-fashioned use of the apparatus furnished by their municipalities.

Fire underwriters also cannot be looked to as full authority or for more than an advisory encouragement toward a high-pressure system. Insurance advice at its best comes largely from men who are already busy on regular work, and who lack in consequence the large amount of time needed for much real investigation of a complex problem such as is presented by any general scheme of fire protection.

It is also unsafe to assume that a city will necessarily be protected by having high-pressure water ready at the street hydrants. If this were true, such cities would show a better fire record than cities that do not have high-pressure hydrants.

It is idle to suppose that because water can be thrown in streams higher than the tops of buildings, the power to do this is also accompanied by an ability on the part of the fire department to get that same water on a fire in the far interior of any building before the building would be practically burned out.

A common and false idea relative to fire department work is the expression "working on the fire," in describing the work of a fire department when an important fire is in progress, whereas in fact the main reason why an interior fire becomes costly and severe is because the firemen do not work on the fire and are able only to work around the fire to check its spread—the fire proper meantime burning itself out.

It is an error to assume that the ordinary city necessarily needs more water for extinguishment of fires. The obscurement caused by smoke; the interference of partitions within buildings; the obstructions of merchandise piled between the hose nozzle and the fire, and the impossibility of throwing horizontal streams into windows at great elevations, cause many fires to be practically inaccessible. Vast volumes of water are used around such fires, often doing merely water damage, and being thus worse than wasted as compared to using the water really required to extinguish the fire.

It is not a foregone conclusion

that portable steam fire engines would continue inadequate if measures were taken for using and not wasting the water pumped by such steamers. Portable "steamers" can pump up enough pressure to raise water to the tops of all buildings except a very few sky-scrapers. They are ready as soon as the hosemen, and the larger cities have more of them than hydrants convenient to a fire.

As to automatic sprinkler systems, there is no question that any building with ordinary contents, equipped with a modern system of this kind in operating order, is a building within which it is impossible for a fire to spread far, so long as the water supply holds out. But the cost of automatic sprinkler systems, the fear of water damage from the constant pressure in the pipes, the cost and annoyances of maintenance, the harassment by insurance inspectors on matters of detail, and the fact that automatic sprinkler equipment work is a special trade not open to general competition, all go to retard the use of such systems by property-owners. Automatic sprinkler systems have extraordinary merit as to putting out fires cheaply; but what is needed for a city is something which can be made compulsory for general use.

The automatic sprinkler system of the present day has had its standard of installation increased in first cost by a variety of refinements which also increase maintenance cost, and is out of the reach of many property-owners who would be glad to realize half of the actual benefit of automatic equipment and avoid three-fourths of its drawbacks at, say, half the cost of standard automatic equipment.

Few, if any, assumptions on high-pressure systems are safe unless actually known to fit the particulars for each city. To avoid assumptions, it would seem best to consider a number of main points in the following order:—The territory to be covered; height up to which to protect the territory; the alarm system; how many bad fires to handle at one time; possible location of fire; how to apply water on, rather than around or at a fire; pressure needed; quantity of water needed per minute; how to convey the water; means of producing the pressure; cost and earnings of various types of high-pressure systems.

In consideration of the foregoing points, it must not be assumed that an ideal must be reached at once, nor that all problems must be at once solved; on the contrary, some fairly important questions can be left for another decade.

As to territory, this is purely a matter of local judgment, and ordinarily means that the central business district of a city is selected to be under high-pressure system protection. Some cities would need and wish to make plans for other than the central district, such as large frame districts, cotton docks, lumber districts, or other localities subject to fast-burning fires, out in the open. This paper is too brief to take up such districts, and will continue on the presumption that the territory is a typical congested business district.

As to height, the point has been made with justice that the tops of occasional tall buildings can be left to shift for themselves; that it is cheaper to let such pinnacles burn, than to raise the whole scheme of protection to meet exceptional heights. The National Fire Protection Association committee on high-pressure systems recommends a height of 100 feet. While this recommendation can be modified up or down somewhat to suit individual cities, the general recommendation certainly appears well taken.

In the matter of alarm systems, years of experience have shown that alarms operating by the early heat of fires are a success. Such alarm systems, or thermostat systems, watch over all parts of a building at once; do not set fire to buildings as

watchmen do, and cost less than watchmen's wages. It would seem within the police powers of a city to make the use of this principle compulsory in all large buildings.

In favouring automatic alarm systems, the main advantage to be sought is to get the fire department into action with a chemical extinguisher so that the fire may be put out without calling any feature of a high-pressure system into service. It is in this manner, which passes almost unnoticed, that the best work of a fire department is done.

If through mischance an alarm is delayed, there remains to certain types of high-pressure systems the advantage that, although the building may be burned half-way to ruin, the fire can nevertheless be controlled.

How many bad fires to cope with at one time is a matter of opinion. Most opinions are to the effect that two fires should be provided for in making plans.

It has always seemed to the writer that no protection system, whether under the name of high-pressure or any other, could be worthy of intelligent attention so long as it ignored or failed in a general provision for dealing with the present difficulties caused by smoke. As one prominent fire department chief expressed it, "We ought not to be called fire fighters, we should be called smoke fighters."

Any fire department officer of experience can relate instances of hose crews being stationed for hours throwing streams into windows from which dense smoke was issuing, only to learn finally that the fire was not reached by the water, although the water seemed to be needed.

Once the smoke difficulty is overcome, once it is possible to apply water quickly and directly on any fire in any large building regardless of smoke or of interior obstructions, just so soon will high-pressure systems be able to deliver water without doing so in vain. In other words, no fire protection scheme is suitable if it fails to provide that water shall strike direct on any fire within the protected territory. It is foolish to assume that firemen can go into impossible places to guide the water. The fact that the above-stated two essentials are not provided for in modern fire department practice is the cause of most of the worst losses and most of the fires which expose cities to conflagration.

For applying water on a fire, in the case of most open-air fires and all fires that can be seen and reached direct by a hose stream guided by a man at the hose nozzle, the ordinary portable hose nozzle carried on the firemen's hose cart is sufficient.

In connection with this again, the intent of existing city ordinances providing for standpipes has been correct so far as the idea has been to furnish the fire department with an extension of the common hose and nozzle to serve as a means of getting water to the fire. But for deep or tall buildings it is not practicable to lengthen the hose nozzle by any usual standpipe. Standpipes are deservedly unpopular with fire departments because they do not lead to the fire, they do not save laddering or climbing the building, and they do not overcome the need for men attempting to work in the smoke in the interior of burning buildings. Standpipes have given much trouble because they are provided with several outlets, and these outlets are in practice open at the wrong places at the time of the fire.

If, however, the standpipe and its multiple outlets idea were applied in modified form, so as to provide the firemen with a hose nozzle or nozzles long enough and crooked enough to reach from where firemen can live, into the smoke and through the building and discharge directly on the fire, this would save all delay in laddering the building, all delay in pulling up hose lines, suffocation or burning of men, and frequent com-

plete failures to deliver the water exactly where it is needed.

It would, of course, be necessary to have nozzles or outlets every few feet apart in all parts of the building which are not accessible to hose streams direct from the outside,—this because it is impossible to tell in advance in what part of the building a fire may begin.

As it would be necessary to have all of the outlets closed except the one or the few needed directly over the fire, it would be necessary that all be permanently closed and remain so except where acted on by the heat of the fire itself. By an arrangement, as described, all that would be necessary for the fire department to do on arriving at the building would be simply to couple their hose to the empty piping system, with the full knowledge that the water would go directly to the fire and that the fusible outlets would be open only at the fire, thus insuring the application of water directly upon the fire. This use of fixing piping with fusing outlets has been successfully tested for many years in thousands of establishments as one of the features of automatic sprinkler systems.

If a municipality can enforce the installation of standpipes which really do not aid the fire department, there would seem no reason why the same municipalities should not use the same authority to provide the fire department with pipe systems which cannot do otherwise than lead the water directly to the fire. There is no reason why a fire department should desire to use a short, straight hose pipe for work on inaccessible fires after they are provided with hose pipes long enough and crooked enough to reach through smoke and obstructions which the firemen cannot pass. It is not essential for this to use any patent devices, valves or fittings.

As to pressure, this, in the main, is not required to overcome the height of buildings. For example, the National Fire Protection Association committee report before referred to would call for less than 50 pounds pressure to overcome elevation of buildings up to 100 feet as proposed, yet the report shows in detail that to also overcome the losses due to friction in pipes and hose, and also furnish excellent nozzle pressure, a hydrant pressure of 225 pounds may in some cases be required.

As regards quantity of water needed per minute, the committee report referred to recommends for a large city a supply capable of prompt delivery at the rate of 7500 gallons per minute, to be capable of working upon further demand up to 20,000 gallons per minute, and further states that the latter amount might have to be doubled under extreme conditions—all of which is true under the present frequent inability to get water on fire within buildings and the consequent necessity of flooding the surroundings of the fire. To use a supply of, say, 30,000 gallons per minute, requires the handling of over 100 tons of dead weight every minute.

But after providing that the water must go directly on the fire, to do which the property-owner must in many cases provide fixed piping, it will be found that it will no longer be necessary to waste such enormous volumes of water and that one gallon of water will do the work of several gallons under the disadvantages of present methods.

As to the means of conveying the high pressure, most opinions favour having all high-pressure water pass through hose handled by firemen. The National Fire Protection Association committee report holds this same view, except as to water for automatic sprinkler systems; it also admits that its recommendation to attach fixed piping to street mains to supply automatic sprinkler systems is debatable, and recommends that such fixed piping be limited in size and supplemented by hose lines leading into the sprinkler system.

The writer believes that fixed connections should be postponed until all large buildings in a high-pressure district are equipped with automatic sprinklers, or equipped with fixed piping having fusible outlets, as advocated on a preceding page, or are of fireproof, steel-frame construction. In other words, do not attach pipe connections to street mains bearing high pressure until all buildings in the district are so well protected or so rigid as to be extremely unlikely to fall. At the outset and to avoid pipe connections, a high-pressure system should always be designed throughout with the idea of passing all water through firemen's hose from hydrants or steamers, whether for inside or outside sprinklers, standpipes, water towers, or any use whatsoever.

From the firemen's hose to the fire the water must, of course, be directed by a hose pipe, and where a short hose pipe will make the stream strike the heart of the fire, well and good; in other cases there is nothing to do except have the hose pipe long enough and crooked enough to carry the water to the heart of the fire.

The means of connecting from the firemen's hose back to the pressure source must depend on the nature of the source of pressure. Few cities need to install a system of street mains as a necessary part of the high-pressure system.

Special high-pressure street mains have one objection in that their value is very generally overestimated by the public and also by insurance agents, who seem to forget that cities with a high-pressure supply are not rated better than those without it. The engineering difficulties in view of the obstructions and franchises already in city streets are very great, and the men best posted declare that in certain cities it is impossible to find advantageous room for another system of pipes to carry high-pressure water.

In the report of the committee of National Fire Protection Association it is pointed out that it is not necessary to have extremely high pressure to operate a system of piping with fusible outlets. For such a system of putting water on the fire it will be found in a fair number of cities that the gravity or Holly pressure and volume already furnished by the existing street mains is adequate.

If the existing street mains and hydrants should lack volume and pressure facilities (say 60 to 80 pounds plus enough to offset heights of buildings, and, say, 5000 to 15,000 gallons per minute) then, if, as is likely, the city has fire engines, these engines should be used. When an engine is used on fixed piping to apply water direct on a fire its efficiency is enormously increased.

Engines arrive at a fire at practically the same time with the hose. Portable fire steamers also have a large pumping capacity (say 10,000 to 25,000 gallons per minute) when used in large numbers as is now done.

Fire boats, which are a species of floating water works, are excellent as to pressure, capacity, and prompt action as a source of high pressure, whether the water be conveyed by hose or special street mains. Where a fire boat is in salt water, the salt water should on no account be used because of its bad effect on the pipes, couplings, and fittings of the high-pressure system.

Salt water need not be used, because the fire boats can draw from suction cisterns placed along the water front wherever deemed needed. The suction cisterns or wells would have to be supplied, in turn, by fresh water from the city mains, which can be done by any city that is not suffering from a fresh water famine.

Bearing in mind that under the plan argued for by this paper, less water and less pressure are needed than by any plan which would expect to control fires by continuing to work at or around and not on a fire, but few, if any, cities will be found to lack high-pressure supply

further than their present public mains or fire steamers or boats now furnish.

Unlike localities subject to large open-air fires, such as are apt to occur in frame districts, resin yards, cotton docks, etc., a district of brick buildings is not quick-burning and will not develop into an open-air fire until buildings are wrecked, roofs off, etc., which cannot occur to a disastrous degree where ready means are provided for putting water on the fire.

The writer does not believe that any city, at present at least, really needs for its business district a special source of high pressure, or a special set of mains, and is of the opinion that such features can better be left to the future. But if a special source of pressure must perforce be gone into, then the lack of an elevation of land need not forbid the consideration of a gravity source.

Gravity is universally recognized as the best source of pressure, and can always be had, because tanks containing two or more million gallons of water mounted on steel towers up to, say, 500 feet high, can be had in the market. A steel tank holding 1,000,000 gallons and mounted on a 300-foot tower can be erected for about $100,000. Such a tank would deliver as much water as twenty fire steamers (in actual service) for over two hours. A million gallons of water will flood more than 6 inches deep all floors of two 10-story buildings covering a ground area of 130 by 100 feet each.

When reliability, maintenance charges, wages for operation, etc., are considered, it would seem that gas or electric power pumping stations need never be resorted to as compared to the cost and merits of a gravity tank plus a moderate pumping capacity which would be needed to fill the tank after each fire, and which could usually take steam at an existing municipal station.

It is true that a large pumping station, for an all-day fire would pump vastly more water than could be stored in a tank. But a fire with water put on it does not take long to control. Furthermore, a city with a high-pressure tank would retain its present equipment of hydrants and engines.

Even in cases where a great supply of water long-continued is indispensable, as for lumber or cotton districts, a gravity tank would reduce the size of pumps needed, would give time to get up steam and start pumps gradually, and obviate any necessity for other than steam-operated pumps.

INVESTMENT AND NET EARNINGS

To arrive at cost and savings of a high-pressure system for a great city, it would seem fair to adopt a basis of a square mile, and for preliminary estimate, adopt a value at risk of $300,000,000 to the square mile. Deduct the small buildings and those fireproof buildings which have little in the form of inflammable contents, and also the buildings already equipped with automatic sprinklers. The remaining property within the square mile will be the property requiring better protection than is now provided.

Against the high-pressure system charge interest, depreciation, current repairs, wages, taxes, insurance, fuel, superintendence, etc. Allow credit for reduced conflagration hazard and also for reduction of ordinary exposure hazard upon all the values within the square mile.

Do not credit the high-pressure system as saving fire cost arising from fires of internal origin, as respects the small or sprinkler-equipped, or fireproof buildings above mentioned. On all other buildings credit the high-pressure system for its aid or power of control of fires of internal origin with resulting reduced cost of such fires.

Along the foregoing lines, which necessarily vary somewhat for every city, it will be found that a high-pressure system which provides

merely for more powerful hose streams than the streams now furnished by portable fire steamers will cost about $750,000 for a square mile, and that for fires within buildings its fire-cost-saving or earning power would be limited to very exceptional conditions and would not net more than an average of about $100,000 a year.

A high-pressure system adopting automatic sprinkler systems as its main feature would, for the same square mile, cost about $2,750,000 and yield net earnings or a fire-cost-saving of about $1,250,000 annually.

Similarly a high-pressure system adopting, as its main feature, the use of piping with fusible outlets, solely for fire department use, would cost about $1,500,000 and yield net earnings or a fire-cost-saving of somewhat more than $1,000,000 annually.

In general, it would seem wholly unnecessary to make radical changes for fire departments, nor in water supply, nor in street mains, nor in hose equipment, nor in ordinances, in order to make the protection of cities radically better and put it on a paying basis; but it is absolutely necessary to so arrange matters that the water shall readily strike at the heart of the fires.

Current Topics

It is not complimentary to engineering talent that while locomotive boilers have increased enormously in size during the past ten or twelve years, close on to 100 per cent. in point of heating surface and grate areas, very little has been done to lighten the labours of the locomotive fireman. In stationary boiler practice, mechanical stokers long since demonstrated their fitness for the work in hand, and it is unusual nowadays to find a plant of appreciable size in which they have not been made to supplant manual labour. Aboard ship mechanical-stoker progress has been slower,—very much slower in fact,—while in connection with locomotives a beginning has scarcely been made. Both afloat and ashore in locomotive practice the mechanical stoker seems to have suffered primarily from the overruling aim to save weight and space, and it is these two considerations which will have a large part in shaping its future in this service. Firing by hand a locomotive with

upwards of 3000 square feet of heating surface is, however, a tax upon human effort much beyond which it will be inexpedient, if not impossible, to go; hence either mechanical stoking must shortly be made amenable to the ways of the locomotive designer, or there must be restriction in locomotive fire-box dimensions or at least in their further growth.

French and German alcohol lamps, both for street and indoor use, are being vigorously pushed in South American markets, and the results obtained with them are understood to have been so favourable that in Venezuela, for example, it is proposed to introduce alcohol lighting systems throughout the country. The burdensome price of illuminating oil has helped largely to bring about this condition of things, aided also by the excessive production of cane alcohol. But the demand for alcohol stoves and motors, too, is being cultivated, and in order to further the whole industry the government tax on all alcohol distilled in Venezuela for use in any of the above-mentioned apparatus was, in March last, suspended for a term of two years. For a like period all customs duties have been removed on alcohol lamps, stoves, motors, and their supplies. Not one of these is manufactured in Venezuela, and an excellent opportunity appears thus to be at hand for a good business in contrivances of this kind. Although gas and electricity are available in the larger towns, oil illumination is used by most well-to-do families, while in humbler homes candles and dips furnish light.

The physiological effect of certain light waves and other ether vibrations upon animal organisms has been a matter of speculation and experiment for many years. The action of the sun in tanning, burning, and blistering the skin must have been observed from remote times, and was no doubt attributed to the sun's ordinary light or heat rays. We now know, however, that sunburn is caused by the actinic rays, or ultra violent rays, that accompany sunlight. The discovery of the effect of light upon the human system in the treatment of certain diseases is of comparatively recent origin. Perhaps the first person to grasp the idea that certain colours of the spectrum might be beneficial in this respect was a physician of the Court of Queen Elizabeth, who recommended that the windows of the sick rooms of smallpox patients be draped with red curtains, believing that this would produce favourable results upon the disease. But he was laughed at for his pains. At the beginning of the last century the announcement was made that the blue ray in a remarkable degree stimulates the development of vegetable life, and many experiments were made in Europe to utilize these rays, but without much success.

If we except the American General Pleasanton, the originator and advocate of the blue light craze in 1872 in the United States, Sir John Lubbock was perhaps the first to give serious attention to the matter of the effect of certain ether rays upon animals. In his book on "Ants, Bees and Wasps," published in 1888, he describes the aversion which ants appear to have to light, especially to purple and violet light, while in their nests, although they seemingly have no dislike to daylight when in search of food. Sir John's experiments at first appeared to indicate that ants were sensitive to, or were irritated by, blue and purple light, inasmuch as they sought the shelter of red or other light in preference to blue or purple light. But further experiments showed that when the actinic rays were screened from the

light thrown upon the ants, they manifested no preference between any of the visible rays of the spectrum. Evidently it was the actinic rays that affected or irritated them. Dr. Finsen, in his experiments with light for the cure of disease, found that earth-worms sought the shelter of red light in preference to the other colours of daylight, this indicating that the rays furthest removed from the actinic rays were the least irritating to the worms. From these and other experiments Dr. Finsen was led to suggest the use of red light with its now well-known favourable results in preventing suppuration and consequent pitting in smallpox. Subsequently, however, he found that the beneficial effects of the red light treatment of this disease were not due directly to that light, but to the fact that the red glass and draperies used to obtain the red light in the sick room keeps the violet and ultra-violet rays from the patient. If the patient be kept in a dark room, the same beneficial results follow as when red light is employed. This result might almost have been deduced from the published accounts of Sir John Lubbock's experiments with the ants.

In this relation it is of interest to note that more recently Dr. Goldman, of Vienna, has made experiments with red light, which indicate that its effect upon vaccinal eruptions is the same as upon smallpox eruptions, that is, it prevents the development of the pustules and lessens the virulence of the vaccine, seemingly also without diminishing the value of vaccination as a prophylactic. Tying a red band around the sore was found equally efficient in preventing suppuration. On the other hand, the very benign effect of the actinic rays in the treatment of lupus by the Finsen method is also well known. In this case the effect is no doubt due to the action of the actinic rays in killing the bacilli.

X-RAYS, which may be considered a form of ether wave, also have a marked effect upon the skin, somewhat akin to sunburn, but more harmful in its effects than sunburn. Hence operators who work with these rays have to exercise much care to avoid ill effects from them. In several cases a lack of careful screening of the head has resulted in baldness. Radium rays, too, some of the emanations from which are regarded at present as a sort of corpuscular bombardment rather than as an ether wave, have a deleterious effect on any part of the body upon which they may fall in quantity. Professor Curie, the discoverer of radium, was among the first to experience this effect, an exposure of 90 minutes to some radium of low activity having caused an ulcerous sore on his arm that was over 50 days in healing, while on another occasion an exposure of only five minutes to some radium of high activity produced a blister and scar on his arm. These results were due to an exposure to very weak, or, as one might say, highly diluted radium; in fact, very little pure radium is in existence. M. Curie has said that he would not venture to trust himself in a room with even one pound of radium, fearing the results upon his body of exposure to such a quantity of this substance.

A RATHER new use of blue light has been reported from Geneva; namely, its use as an anesthetic in dentistry. In the course of some experiments to ascertain the effects of light of different colours upon the nerves, Professors Redard and Emery found that blue light was very soothing. The somewhat remarkable statement is made that a 16-candle-power blue light, directed upon the eyes of a patient for three minutes, caused him to lose sensitiveness to such an extent that a tooth was painlessly extracted, without after-effects

of any kind. Whether the anasthesia was general or only local is not stated. It is very probable that had General Pleasanton been a true scientist and a skillful experimentalist he might have made some discoveries of value to the world, for, as Dr. Finsen himself has said, "The General was on the right track." In 1877 Pleasanton published a book with the following explanatory title: —"The Influence of the Blue Ray of the Sunlight and of the Blue Colour of the Sky, in developing animal and vegetable life, in arresting disease, and in restoring health in acute and chronic disorders to human and domestic animals, as illustrated by the experiments of Gen. A. J. Pleasanton and others, between the years 1861 and 1876." The book is printed on blue paper, and abounds in fallacious and dogmatic statements. One of his dicta is, "Light is the great source of terrestrial electricity, magnetism and heat." Quite a large portion of the book is devoted to testimonials from physicians and various others, relating to the efficacy of the blue ray treatment in cases of general ill health, rheumatism, etc. Pleasanton believed that the results claimed by him were due the "juxtaposition of plain uncoloured glass and blue glass in the passage of sunlight and the transmitted blue light of the firmament, and the eliminated blue rays of the sunlight through them respectively, which evolves an electromagnetic current, which imparts to vegetation or animal life subjected to it an extraordinary impulse to the development of their respective vigour and growth." He obtained a patent for his so-called discovery, and for the method of its application.

So much has been accomplished in recent years in utilizing waste products of all kinds that the unutilized waste heat in the exhaust gases of gas and oil engines has seemed a reproach to twentieth century progress. Latterly, however, the idea of turning this carelessly abandoned energy to profitable account has received some attention, and at least one attempt has been made to apply it to steam raising. While the available particulars of the experiment are not very specific, they are at any rate indicative of work along a commendable line.

In the practice of medicine a correct diagnosis is nearly always essential at the beginning of successful treatment: Unless the full significance of symptoms is appreciated, there is little certainty of a prescription's remedying the trouble to which it is applied. These facts pertain with the same force to the life of a community as they do to the life of an individual, and there is as much need to-day for expert supervision of the machinery with which the world's work is done as for medical oversight in the interests of health. We are to-day suffering from an appalling recurrence of accidents and conflagrations. Disasters on land and sea have followed one another with alarming frequency, and in an unfortunate number of cases the cause of calamity has been resolved into carelessness. Hence, it behooves every worker to strive to attain that alertness of mind and body which alone has power to decrease the suffering and losses that hang like a dead weight upon twentieth century civilization.

Frequently it is the case that the cause of an accident or a great fire is an almost insignificant event or condition. Proper inspection is the remedy; in fact the great majorty of calamities succeed in happening because of inadequate oversight. It is the little links which finally complete the fatal chain. The half-empty or wholly dry fire pail is

one of the most common sins of omission. It is not unusual to find three or four hundred thousand dollars invested in an office building or hotel, with a power plant designed according to the most advanced practice of the day, while in the corridor the fire pails go empty because inspection is perfunctory. Another instance of criminal carelessness is found in street boxes of city fire alarm systems, that are unprovided with either keys, keyless doors, or printed instructions as to where the nearest key can be obtained. It is preposterous to spend large sums of money on automatic electric fire signalling apparatus in the attempt to save the priceless seconds at the beginning of a fire, if the keys to all the street boxes are not to be instantly available in time of need; and yet this condition is to-day in existence in more than one large city which prides itself on the efficiency and speed with which its fire department answers an alarm.

Burning incandescent lamps out-of-doors in broad daylight are generally regarded as nothing but a careless waste of money by an operating company. To the lineman at work upon or near the supposedly "dead" lines on poles in the daytime, the little thoughtlessness of forgetting to cut out the circuit at the central station often becomes a matter of life and death. Other fertile causes of trouble are the common defects in discipline and operating care on electric and steam railways. Mistaken orders, forgetfulness, attempts to "steal" switches, leaving cars on sidings with the overhang fouling the main line, long hours without sleep, non-enforcement of certain rules winked at by the management, false economies in the reduction of the number of employees —these and other faults might be multiplied indefinitely, every one likely to cause disaster of terrible magnitude. Until the managers of great industrial organizations become thoroughly aroused to the necessity of providing adequate inspection in every department which deals with forces capable of annihilating life and property, safety must still be perverted. Doubtless it is impossible to prevent all accidents, because of the limitations of human knowledge, but as far as intelligent and never-tiring effort is concerned, no stone should be left unturned to secure it.

The extent to which labour-saving machinery of the ponderous variety is employed at the present time is excellently illustrated in the great iron ore properties of the American Northwest. The number of steam shovels, for example, employed in stripping Mesaba range mines is just now the greatest in the history of the range. There are not less than thirty-three of them, nearly all of great size and power. The average work of these shovels for ten hours is 3000 tons each, and as some of the shovels are worked day and night, the amount of earth moved by them is enormous. In addition to all these which are engaged in development operations alone, thirty-six shovels are occupied in mining at the open pit properties of the range, and a dozen or more others are loading stock piles at underground mines on the range, so that altogether there are more than eighty steam shovels at work in the district. In size they vary from 40 to 50 to 110 tons each.

PORTRAIT BY FARCLAY BROTHERS, NEW YORK

JOHN VAN VLECK

MECHANICAL ENGINEER FOR THE INTERBOROUGH RAPID TRANSIT COMPANY, NEW YORK

SEE PAGE 519

INDEXED

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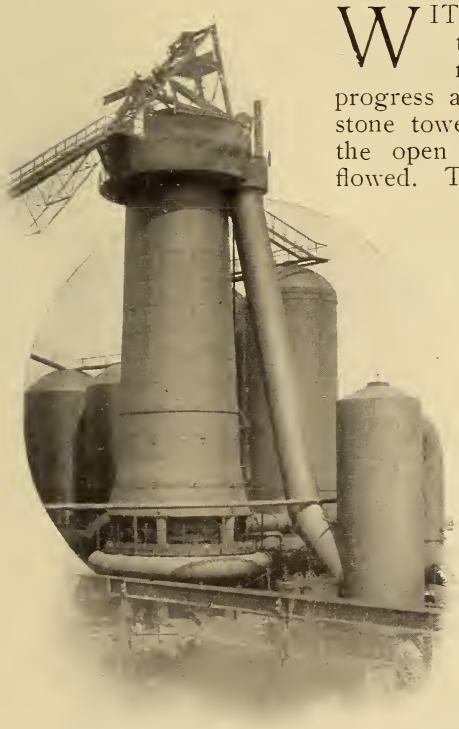
CLEANING BLAST-FURNACE GAS

ITS ECONOMY IN IRON MANUFACTURE

By Axel Sahlin



A MODERN BLAST FURNACE WITH GAS CLEANING EQUIPMENT

WITHIN the memory of men yet active in the industry, the blast furnace, that mighty machine so vital to human progress and development, consisted of a square stone tower surrounding the furnace shaft, from the open top of which the ignited gas freely flowed. The only duty then performed by this potential source of energy was to illuminate the surrounding country at night with its lurid flames. A water-wheel in an adjacent stream, or a primitive steam engine, supplied the feeble blast. Slag issued continuously through the open front, in the fore-hearth of which the melted iron was slowly collected.

Theoretical knowledge of the processes taking place inside the furnace was then even more limited than it is to-day, when the technical world, in spite of all vaunted progress, acknowledges its inability to explain why Mr. Gayley, by abstracting one or more grains of moisture from the air fed into the furnace, can practically, by weights of fuel and product, demonstrate a saving in coke consumption of about 17 per cent., while learned professors emphatically declare that this saving is theoretically impossible; hence, non-existent.

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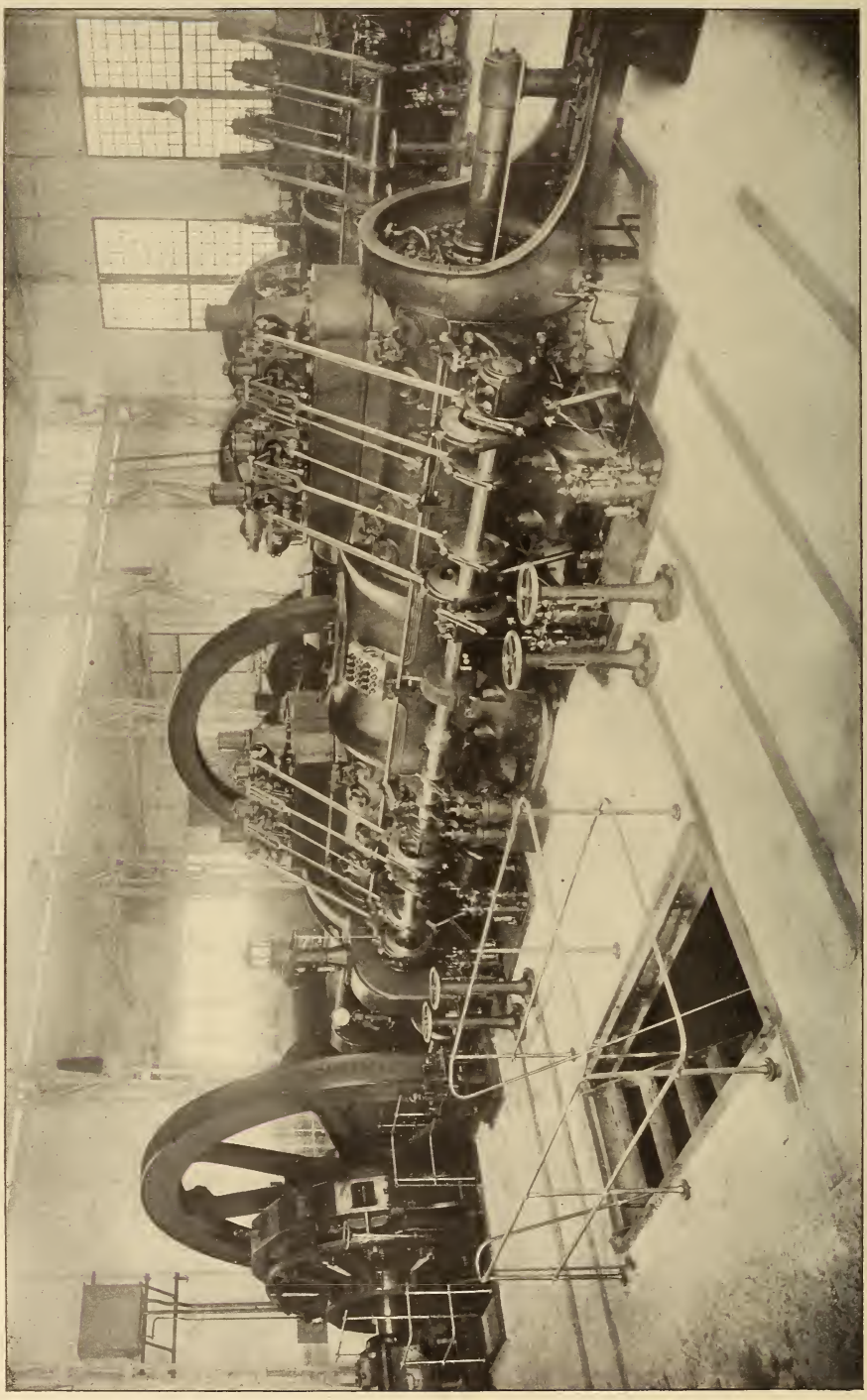


TWO TANDEM NURNBERG GAS ENGINES, OF 1200 BRAKE-H. P. EACH, DRIVING DIRECT-CONNECTED GENERATORS AT THE RHEINBADEN WORKS OF FRIED KRUPP, ESSEN, GERMANY, OPERATED BY BLAST-FURNACE GAS

During the long term of activity of the pioneers in the profession, momentous improvements have been made in the manufacture of pig iron. Hot blast has been introduced. The furnace tops have been closed, and the gas has been employed for producing heated blast and power. The closed slag notch and iron tap have made possible a better utilization of the heat in the lower part of the furnace. The modern steam engine, connected with blowing cylinders having positive valves, has given us a more effective blast. Mechanical distributors regulate the charging of the materials into the furnaces. Powerful unloading devices now handle the ever-growing bulk of material devoured by the hungry fires. Forged copper tuyeres which resist for several months the action of the dripping iron and the fiery blast, as well as machines for the mechanical closing of the tap hole through which the iron issues, have limited the stoppages of the furnace to a minimum. Pig-breaking and pig-casting machines have made possible the rapid removal of the increased product, and granulation of the slag by flowing water has facilitated the economical handling of this waste material.

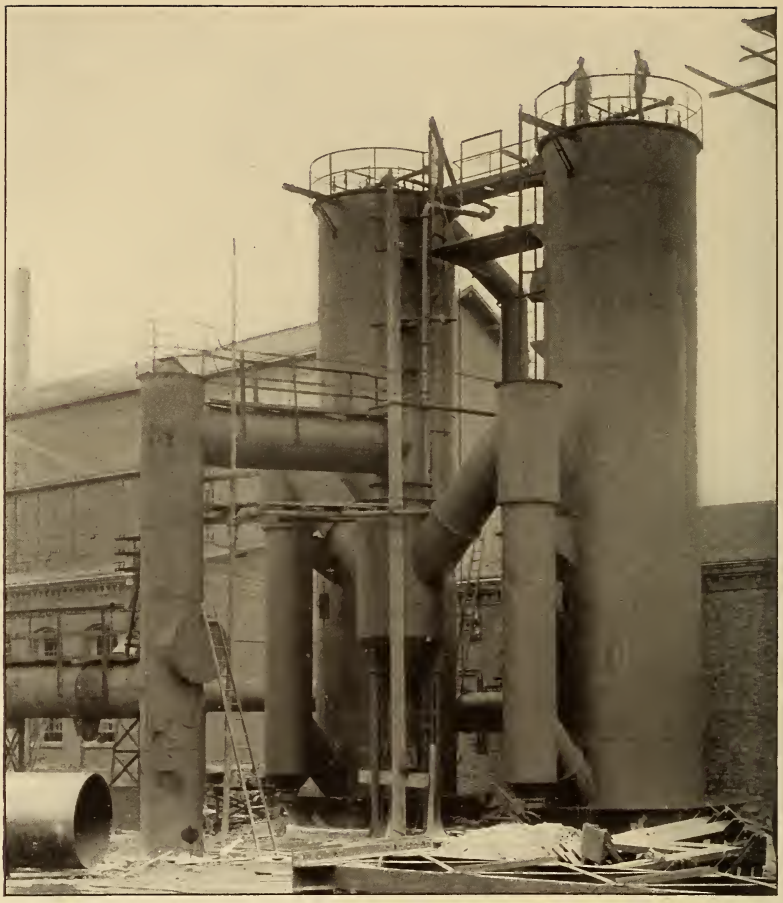
All these inventions combined, with others too numerous to mention here, have made it possible for the single modern blast furnace to reach an output of from 600 to 800 tons of iron in a single day, or over 20,000 tons in a month. And still the work of progress is going on. We who now live have seen only the beginning of the development of the great and splendid iron industry. An ever-increasing army of men with brains and energy unceasingly strive for economy and improvement of the processes and machinery, the guidance of which is their life work. So does Mr. Gayley's discovery of the effect of dry blast, or perhaps, rather, uniformly dry blast, which has so fully been placed before the technical world during the past few months, point the way to a possible saving in Great Britain, Germany, and America alone of about five million tons of coke per year.

Without having the right to claim any personal invention, the writer, at the meeting of the Iron & Steel Institute in May, 1905, called attention to other hitherto generally neglected means of economy in the manufacture of pig iron, viz.—the thorough cleaning of the millions of cubic feet of gas issuing every hour from the top of the blast furnace, before this gas is utilized for development of heat or power. There is nothing particularly unique in the means of obtaining this result, but the effect of clean gas is most marked and is at last gradually being recognized.

The heated blast which enters at the bottom of the furnace, as is well known, rapidly combines with the carbon of the glowing coke in front of the tuyeres. Passing through numerous stages of reduction and re-oxidation, it finally reaches the furnace top, converted into a gas mixture containing nitrogen, carbonic oxide, carbonic acid, steam, and smaller quantities of sulphurous acid, ammonia, hydro-carbons, etc. In their upward flow, these gases carry with them light particles of ash, coke dust, and fine ore, until they issue at the tunnel-head of the furnace as a thick, bluish cloud, from which a rain of small particles of solid material continuously falls.

The amount of fine and coarser dust which the gas carries away from the blast furnace when it is working properly may amount to from 1.3 to 5.3 grains per cubic foot. A moderate-sized modern blast furnace will send out every hour about 2,500,000 cubic feet of gas containing from 460 to 1850 pounds of solid dust. The quantity of dust depends partly on the kind of materials charged, partly on the rate of driving the furnace, and, finally, on the condition of the furnace at the time.

If the furnace slips, that is, if the gradual descent of the material is interrupted by sudden rapid falls, the



A ZSCHOCKE GAS CLEANER, MADE BY ZSCHOCKE'S MASCHINENFABRIK, KAISERSLAUTERN, GERMANY

instantaneous chemical changes of large quantities of ore will liberate considerable quantities of gas, which will carry with it not only dust, but larger pieces of both coke and ore. Instances are on record where such slips have emptied the entire furnace barrel down to the boshes, scattering glowing pieces of coke and ore over a wide area around the furnace. These violent slips have then assumed the character of explosions, which may be so severe as to cause the destruction of the furnace top. Ordinarily, however, when the furnace is working with anything like fair regularity, the quantity of dust will come within the limits just named. But even this quantity is sufficient at times to prevent wholly or partly the ignition of the gas in stoves and boilers. When the dust is removed, the furnace gas will readily ignite at low temperature.

Before the construction of engines driven by blast furnace gas, the metallurgist calmly submitted to the use of the gas as it left the tunnel-head. If the foreman reported that the gas would not burn, he was simply told to fire good coal under the boilers, for which an excess of gaseous fuel at no special cost was available. The writer knows some blast furnace plants where the sum of 3d. per ton of iron produced has

been wasted by such firing of coal in the effort to ignite the "thick and limy" blast-furnace gas.

In Great Britain, even up to the date of this writing, at least 75 per cent. of the coke-fed blast furnaces in operation are still without any means for purifying the gas, which is carried from the tunnel-head through a single downtake into a brick-lined flue placed alongside of the furnaces and connecting with stoves and boilers. Regularly every four, or, at the most, every six months, the furnace plant is prepared for a stoppage with a waste of a certain number of tons of coke per furnace. The blast is then taken off. The three furnace crews, which work the British blast furnaces on 8-hour shifts, are called out. Beer and beer money are freely supplied as an encouragement for the hard and unwholesome work to be undertaken.

Explosion doors on the flue are removed; bricked-up doors are opened; and the men set to work with shovels, pails and wheel-barrows to dig out and hoist to the surface the dust which often fills the flue to within 18 inches of the crown of its arch.

The heat, the noxious gases, and the dust make the work exceedingly laborious and disagreeable. Should rain add to the discomforts, as often happens, the entire place around the furnace is rapidly covered with liquid mud and presents an appearance of utter and hopeless disorder. Gas not being available, electric lights cannot, as a rule, be used. The work is, therefore, carried on during the night by the light of lamps and torches.

After from 18 to 24 hours of hard digging, the flues are pronounced cleaned; the explosion doors are closed; the doors through which the dust has been wheeled out are again bricked up; a considerable quantity of coal is wasted under the boilers in order to raise steam, and the furnace plant is started.

In nine cases out of ten, it is found

ZSCHOCKE GAS CLEANING PLANT AT THE BURBACH FURNACES, BURBACH, GERMANY

that the furnaces are more or less chilled, and that the iron produced is not of the grade desired. Arches of half-reduced material bridging the furnace shaft,—so-called scaffolds,—have been formed; slips take place, and some unprofitable days of anxious work follow the enforced interruption, while dust is again beginning to accumulate in the same flues, until another stop becomes necessary.

In the meantime, the lighter dust does not remain in the gas flue, but is carried over into the stoves. At least every three months, it is the practice to stop one of these expensive apparatus. It requires a week for a large brick-lined stove to cool down sufficiently for men to enter into its interior. It is then found that the vertical flues are partly filled, that dust has accumulated at the top of the brickwork, and that the passages at the bottom of the stoves are more or less clogged. Two or three days of strenuous work for four men is required to clean a stove. When the, at best, imperfect cleaning is completed, the stove is again closed; gas is turned on and freely burnt during about 48 hours before the stove regains sufficient temperature to heat the blast properly. As a whole, about ten days have, therefore, been wasted.

To avoid a reduction in the capacity of the furnaces during these periodical stoppages, it has become a rule to provide a fourth stove. Such a stove costs, complete, from £3500 to £5000,—a not inconsiderable amount as a first outlay. As a rule, it may be said that stove cleaning is going on at a plant of two furnaces during about one half of the year. The loss in permanent efficiency is also very considerable, because the dust cannot be entirely removed from the inaccessible portions of the stoves.

A number of years ago, the writer was called on to examine and report on a blast furnace in Virginia, U. S. A., which had not been successful. Judged from its outside appearance, the furnace plant seemed to be in excellent condition. All the machinery was of ample capacity; the stoves especially appeared efficient. An examination of the furnace records revealed, however, that the furnace had been blown in successfully and had worked well for about six weeks. At the end of that time, the blast temperature gradually began to decrease.

During the first month the heat averaged about 1350 degrees F. This gradually fell to 1200, 1100, 1000, 900, until at the end of six months the highest blast temperature reached was 850 degrees. The coke consumption had increased proportionately, and the furnace was put out of blast as unprofitable. The writer was long at a loss to account for this. Inquiries from men left to guard the place failed to bring information. At last it was found that the departed management had left a set of drawings of the furnace and stoves. These drawings were beautifully made and bore the signature of a Westminister civil engineer who evidently had never had any practical experience with blast furnaces, and certainly not with blast furnaces to meet the requirements in the American Southern States.

The drawings revealed that this engineer, recognizing the value of a large heating surface, had built the flues of the stoves with alternate bricks protruding from the straight wall, forming a zigzag surface. Every protruding brick formed a ledge on which dust could and did lodge, and as the non-conducting dust accumulated, the excessively large heating surface of the stoves decreased in value. The uneven surfaces of the flues made cleaning impossible. The only thing to be done was, therefore, to demolish the brickwork in the stoves at the expense of several thousand pounds.

Fortunately, most blast furnaces are designed by practical men, and the fatal error of building stoves with surfaces which cannot be cleaned or

reached is not often encountered. Nevertheless, it is a fact that all brick stoves suffer permanently from the deposit of dust on their heating surface, and even the addition of a fourth stove will not maintain the original efficiency of the blast-furnace heating apparatus.

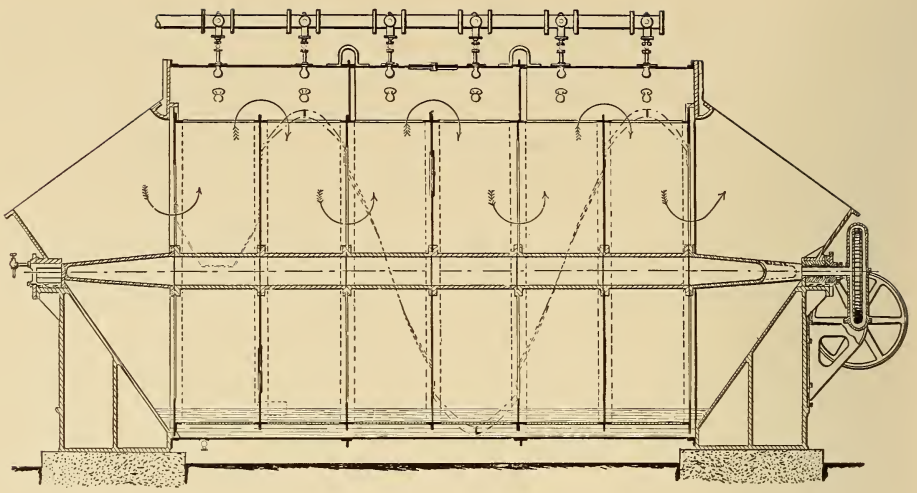
When the gas arrives under the boilers, it is met by the cold surfaces of steel plating or tubes. When the gas is "limy," that is, carries an excessive quantity of dust, ignition is prevented or retarded. If ignited, the gas deposits a large percentage of the dust held in suspense, which rapidly covers the interior of the boiler setting, and lodges in flues or on top of tubes. Wherever dust settles, the temperature of the plate is reduced, and internal strains are caused by the local contractions in the various plates, often sufficient to develop cracks or to ruin the boilers. At the same time, the heating surface covered with dust is practically valueless. For this reason the cleaning of the boiler settings is a continuous and laborious task at every blast furnace using uncleaned gas.

At a certain plant known to the writer, the board of directors had appropriated money for water-tube boilers; at the same time they declined to provide means for gas-cleaning apparatus. As a consequence of this unwise policy, the settings of each one of the delicate boilers have to be opened twice a week and cooled down, so that men can enter to shovel away the dust which accumulates from 2 to 3 feet deep inside of the brick walls. Under such circumstances a ridge of dust is found on top of every tube, cooling the steel there and causing the tubes to bend permanently downward. When this distortion has reached a certain point, it is necessary to exchange the tubes so as to ensure against collapse. Repairs at such a plant are, therefore, excessive.

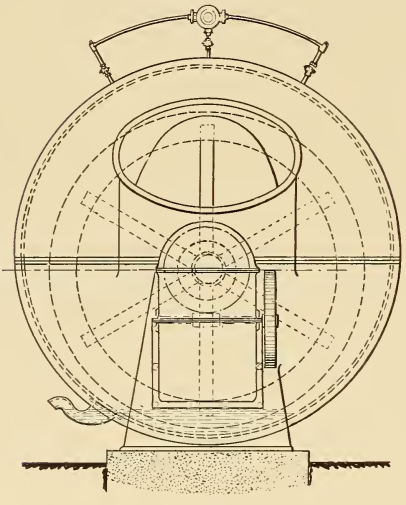
By cleaning the gas, the difficulties and losses pointed out could be prevented. The fourth stove for each furnace could be dispensed with, and the three stoves required, which would remain clean, could be built with about 10 per cent. less heating surface than now is the practice. The boiler plant could be kept more permanently active. About 10 per cent. of the boilers are usually laid off for cleaning the settings. This would not be necessary. The remaining boilers would gain at least 5 per cent. in efficiency. The number of men engaged for carrying on the cleaning work could be reduced. The coal now often fired under the boilers would not be needed. In addition, better ignition would, as demonstrated and proven in certain Continental works, cause a direct saving of about 20 per cent. of the gas used in stoves and boilers, or from 3000 to 5000 potential gas engine horse-power per blast furnace.

The preceding may suffice to indicate the importance of cleaning the blast-furnace gas and the savings which are realized by so doing. But there are degrees of purity, and according to the different uses to which the gas is later to be put, different methods of cleaning, with corresponding results, should be adopted. The gas engine would do its best work with absolutely pure gas; it does not work well with gas containing above about 0.044 grain per cubic foot. Stoves and boilers, on the other hand, do not require the cleaning to be carried beyond 0.130 grain per cubic foot of gas.

The early blast-furnace gas engines failed because of imperfect cleaning of the gas. The gas engine repairs still continue heavy, because sufficient grit is generally left in the gas to gradually cut the working surfaces or clog the valves of the engines. It may, therefore, be said that when the gas is to be used in engines, the cleaning cannot be carried too far, and the saving in the cost of producing power by gas as compared with steam engines is quite sufficient to warrant the outlay in additional machinery and power plant



LONGITUDINAL SECTION OF THE SAHLIN CLEANER



AN END VIEW

for cleaning purposes. For use in stoves, furnaces, kilns, or under boilers, it would, on the other hand, be an extravagance to seek to remove the very last fraction of a grain.

The cleaning of the gas should, therefore, be carried on in separate stages, and the writer has advocated the adoption of a three-stage process. The first stage should consist of the employment of gravity and centrifugal force to deposit such heavy particles as can be separated by these forces. The proper instrument for doing this is, unquestionably, a circular dust-catcher, into which the gas is introduced near the bottom in a tangential direction, and whence it is removed through a central pipe connecting with the top of the dust-catcher. The larger such a dust-catcher is the better. At a modern plant in the North of England, a dust-catcher having a diameter of 21 feet, and a height of 80 feet is employed with good results. This first stage of the cleaning is performed without any tangible cost or expenditure of power.

When issuing from the dust-catcher the gas may contain from 0.66 to 2.64 grains per cubic foot. This dust is so fine that it will float in the gas for an indefinite period. It must be removed by cooling the gas by contact with water and with surfaces sprayed with water. For this purpose different machines have been invented, all of which may be divided into the following classes:—

1.—Stationary cleaners.

2.—Slowly-revolving fresh-contact cleaners.

3.—Rapidly-revolving or atomizing cleaners.

The stationary cleaners were the first to be employed. The shape of

a vertical cylinder was the cheapest and most natural and was therefore adopted. The cylinder was filled with coke, wood shavings, grids of iron, wire, etc. Through this gas was passed with or without the addition of water. When first started the apparatus did its work well. But it was soon found that dust was deposited on the surfaces of the obstructing material, and the cleaner became clogged. The next step was to double the number of scrubbers and to clean one set of scrubbers while the other was working. This was laborious and expensive.

More recently, stationary cleaners, which work well, have been designed in such a way that water falling over the grids removes the dust as fast as it is deposited, at the same time leaving the cleaning surface wet and ready for the deposition of additional dust.

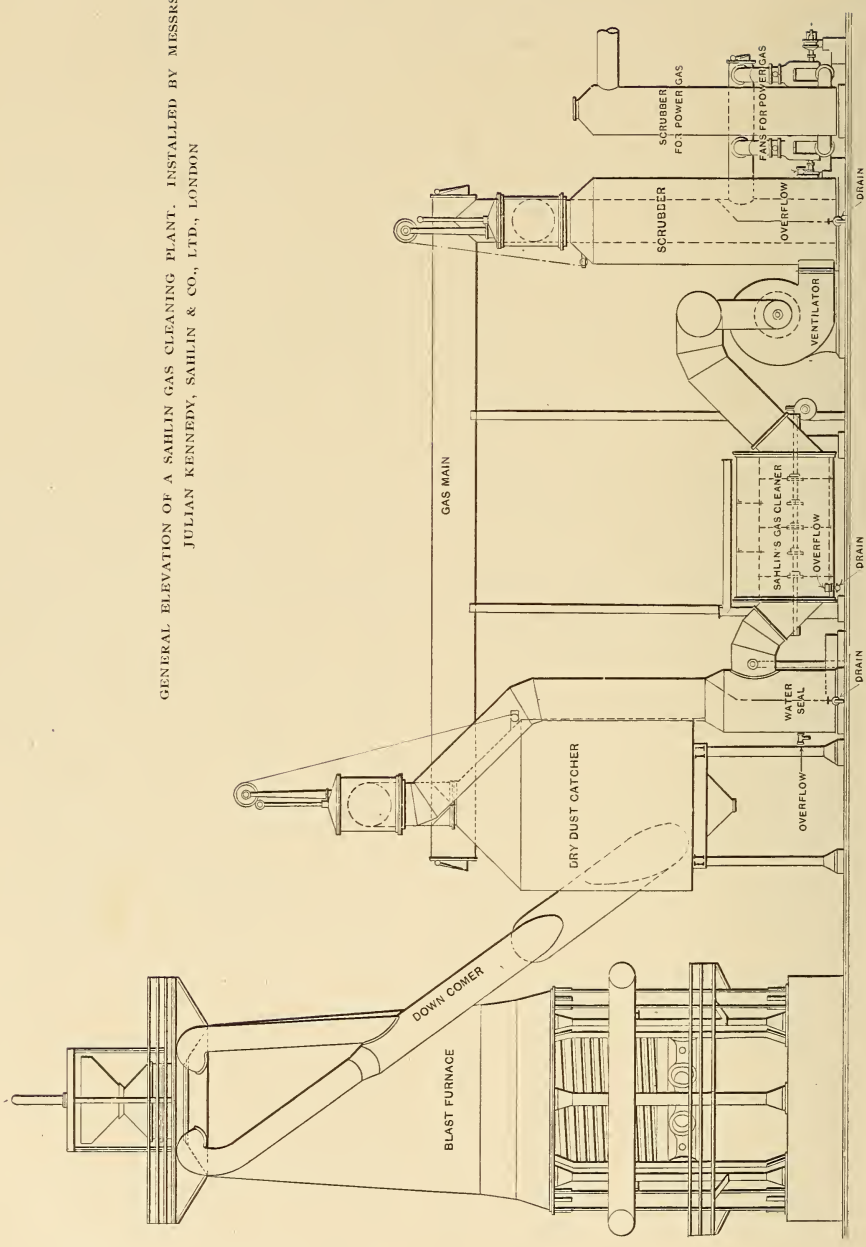
The firm of Zschocke, at Kaiserslautern, Germany, have designed cleaners of this type, which work successfully and for long periods of time. They consist of the usual vertical cylinder in which, at intervals, are placed grids of triangular wooden slats, over the apexes of which numerous water sprays deliver a constant rain of water. The gas enters at the bottom of the apparatus and departs at the top of the cylinder. Zschocke apparatus is installed at several German plants, for instance, at Rombach, where all the gas from seven blast furnaces is cleaned; this results in a saving of about 20 per cent. of the caloric energy of the blast-furnace gas, which is thus available for departments not connected with the furnace plant.

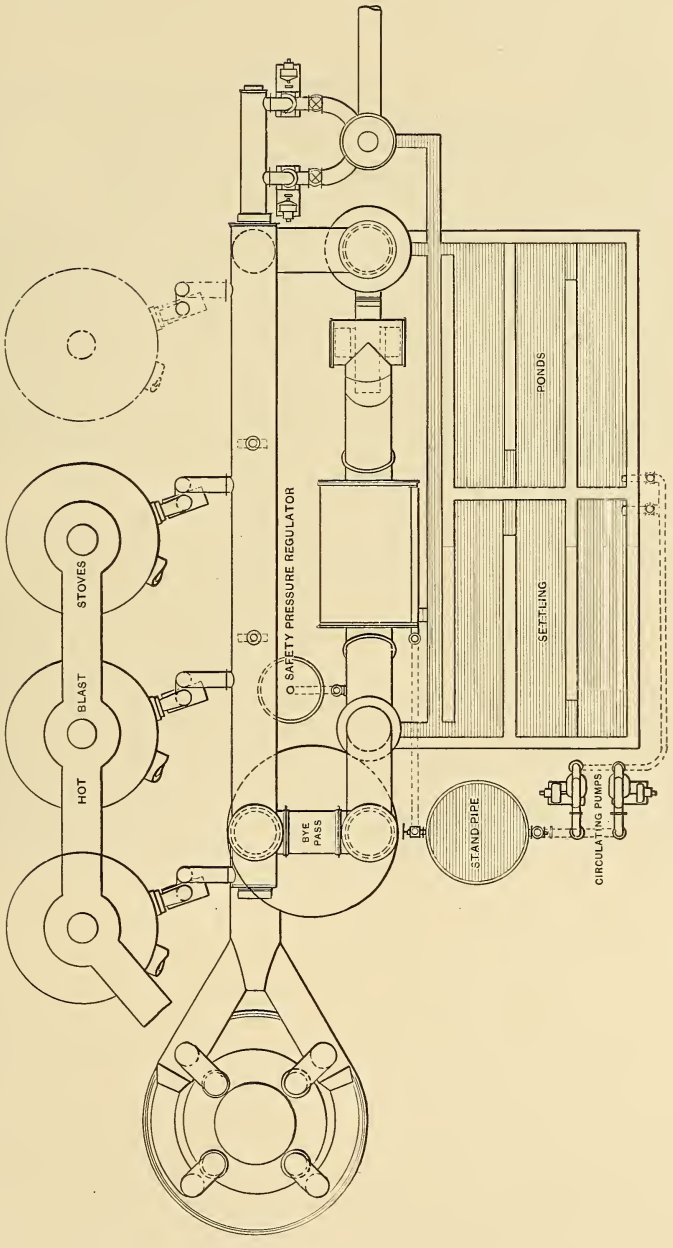
The second type of apparatus employs a series of slowly-revolving perforated steel plates which are automatically cleaned by dipping into water. An apparatus of this class, invented by Mr. Bian, consists of a horizontal shaft revolving inside of a horizontal cylinder. On this shaft are mounted a number of circular discs of perforated plates. The lower half of the cylinder is filled with water. As the discs slowly revolve the perforations present dripping wet edges and a cold surface to the gas. The latter is forced to travel lengthwise through the cylinder and passes through the numerous perforations of the plates, depositing its dust and becoming cooled at the same time, and, therefore, dried.

The writer has designed another slowly-revolving cleaner. Instead of employing discs, as does Mr. Bian, the Sahlin cleaner, as shown in the illustrations on pages 442, 444 and 445, makes use of a horizontal cylinder, the walls of which are perforated. This cylinder revolves within a cylindrical containing chamber, and is supported from a turning shaft alternately by spokes and discs. The outer containing cylinder has apertures at its ends for the admission and discharge of the gas. The bottom of the outer cylinder is filled with water to a depth of 6 inches below the lowest point of the perforated drum. The horseshoe-shaped space between the cylinder and the drum is closed by plate diaphragms placed close behind each of the spoke wheels supporting the perforated drum. The top of the drum is sprayed from sprinklers fitted in the top of the outer cylinder. Near the gas inlet end a water-sealed overflow is bolted to the outer cylinder. To the outside of the revolving perforated drum a spiral conveyor is bolted, which scrapes the dust collected in the bottom of the cylinder towards the inlet end and the water-sealed aperture through which the dust is discharged. The inside drum is kept slowly revolving.

The effect of this apparatus is similar to that of the Bian apparatus, the gain being that where Bian fills one-half of the outer cylinder with water, the Sahlin apparatus uses water only at the bottom of the cylinder. A very much larger area of perforated surface is, therefore, available for the passage of the gas; in other words, the apparatus, although of the same

GENERAL ELEVATION OF A SAHLIN GAS CLEANING PLANT. INSTALLED BY MESSRS. JULIAN KENNEDY, SAHLIN & CO., LTD., LONDON





PLAN OF A SAHLIN GAS CLEANING OUTFIT

THEISSEN GAS WASHING PLANT AT THE CARGO FLEET IRON WORKS, MIDDLESBORO. THERE ARE THREE WASHERS, EACH WASHER CAPABLE OF CLEANING ALL THE GAS COMING FROM A BLAST FURNACE MAKING 1300 TONS OF CLEVELAND IRON PER WEEK

size as that of Bian, has less weight and larger capacity. Slowly-revolving apparatus of the Bian type is used at several works in Luxembourg and France,—at Duedelange, for instance, where the entire quantity of blast furnace gas is cleaned with excellent results.

The first of the atomizing apparatus was, naturally enough, the blast fan or ventilator. This apparatus had been well worked out and could at once be used in the shape in which it was sold in the open market. The water was passed into the casing of the ventilator through pipes in the circumference. In other instances, the ventilator shaft was made hollow and water was delivered into the center of the fan-wheel through the central opening.

Such fans are effective cleaners, but require considerable power in proportion to the volume of gas cleaned. At the de Wendel Works, at Hayange, the entire quantity of gas from seven blast furnaces is cleaned by fans only, and with gratifying results. The cleaning is carried on in three stages, namely:—

1.—By means of large fans, which leave about 0.2 gram of dust per cubic metre of gas, which is then sent to the stoves and boilers.

2.—The second cleaning is carried on in smaller and more rapidly-revolving ventilators and leaves less than 0.1 gram of dust per cubic metre of gas.

3.—This small quantity is still further reduced by passing the gas through a scrubber before it is carried to the large central electric power plant, which has a capacity of 7000 H. P.

In 1900, Mr. Theissen designed a modification of the ventilator. The Theissen apparatus consists of a conical shell revolving on a central shaft placed inside of a conical containing shell. To the outer surface of the inner cone, fan blades are riveted at different angles. Gas enters the apparatus at the small end of the containing cone, and is drawn off at the large end. Numerous pipes arranged along the sides of the outer shell admit water. The gas is thoroughly

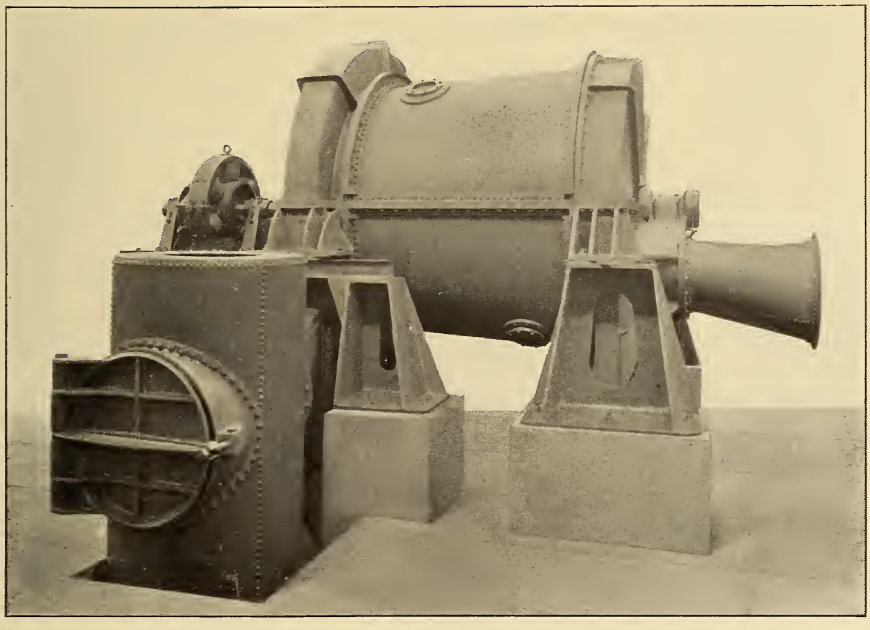
cooled, that is, dried, and is freed from dust.

A gas-cleaning plant consisting of three Theissen apparatus is cleaning the entire quantity of gas produced by two large blast furnaces at the Cargo Fleet Iron Works, Middlesboro. A very high degree of cleaning is reached, but both the Theissen apparatus and the ventilators require considerable power, and it is, therefore, more economical to employ apparatus which more nearly approaches automatic working for the larger portion of the gas, reserving for the atomizing machines the work of finally cleaning the gas for engine use only.

As near as it has been possible to ascertain, the blast furnace working according to the old methods at present employed by a majority of plants, will utilize for heating the hot-blast stoves 40 per cent. of the gas produced, and for firing under boilers 60 per cent. In addition, a certain quantity of coal is in most cases burnt under the boilers. A blast furnace yielding, say, 2,500,000 cubic feet of gas per hour will produce, with 50 per cent. ore and good coke, about 240 tons of iron per day. It will require, for economical working, a boiler plant of about 2000 H. P., which, with fairly good engines, can be transformed into 4000-brake horse-power at 750 cubic feet of gas per hour per B. H. P.

By substitution of gas engines, a brake horse-power may be had with the expenditure of 105 cubic feet of gas, corresponding to 210 cubic feet of gas per boiler horse-power. Instead of using 1,400,000 cubic feet of gas per hour for power purposes, 420,000 cubic feet will be sufficient. This leads us to a saving at this part of the process of about 980,000 cubic feet of gas per furnace per hour.

In the stoves we consume about 1,050,000 cubic feet of gas for heating the blast. Experience has proven that 20 per cent. of this quantity, 210,000 cubic feet, may be saved by



A THEISSEN WASHER FOR BLAST-FURNACE GAS. MADE BY MESSRS. RICHARDSONS, WESTGARTH & CO., LTD., MIDDLESBORO

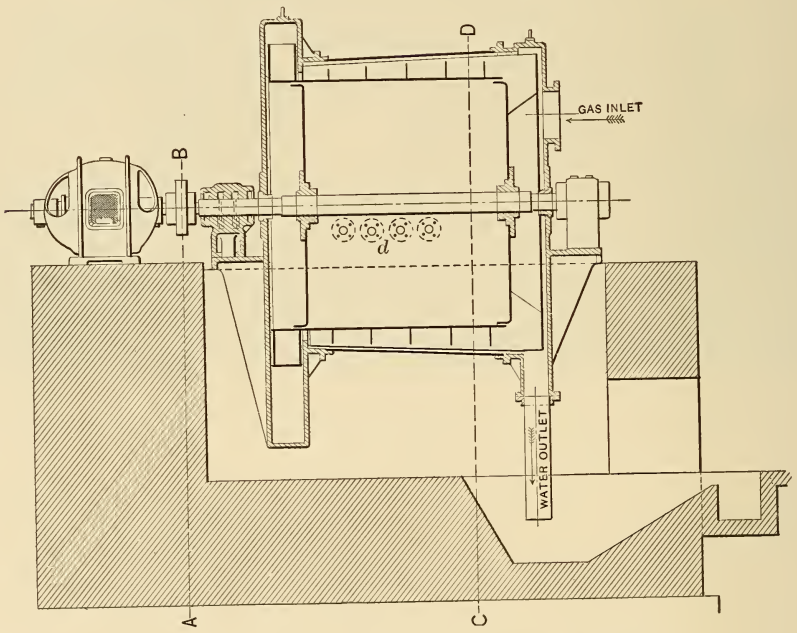
utilizing cleaned gas. The saving effected by gas engines and cleaned gas employed in the stoves, therefore, amounts to about 1,200,000 cubic feet per hour, or approximately from 45 to 50 per cent. of all the gas produced by the furnace. This important source of power is thus made available for purposes not directly connected with the production of pig iron.

In the first cost of substitution of gas engines for steam engines or steam turbines, there is very little, if anything, to be saved. Gas engines with gas-cleaning apparatus to-day cost somewhat more than a modern equipment of high-class steam blowing engines, boilers, and condensers. As the patents covering important details of the gas engine expire, and as the construction of this class of engine is taken up by a larger number of manufacturers, it is, however, certain that the price will be reduced so that even in the first cost of installation a considerable saving will be effected.

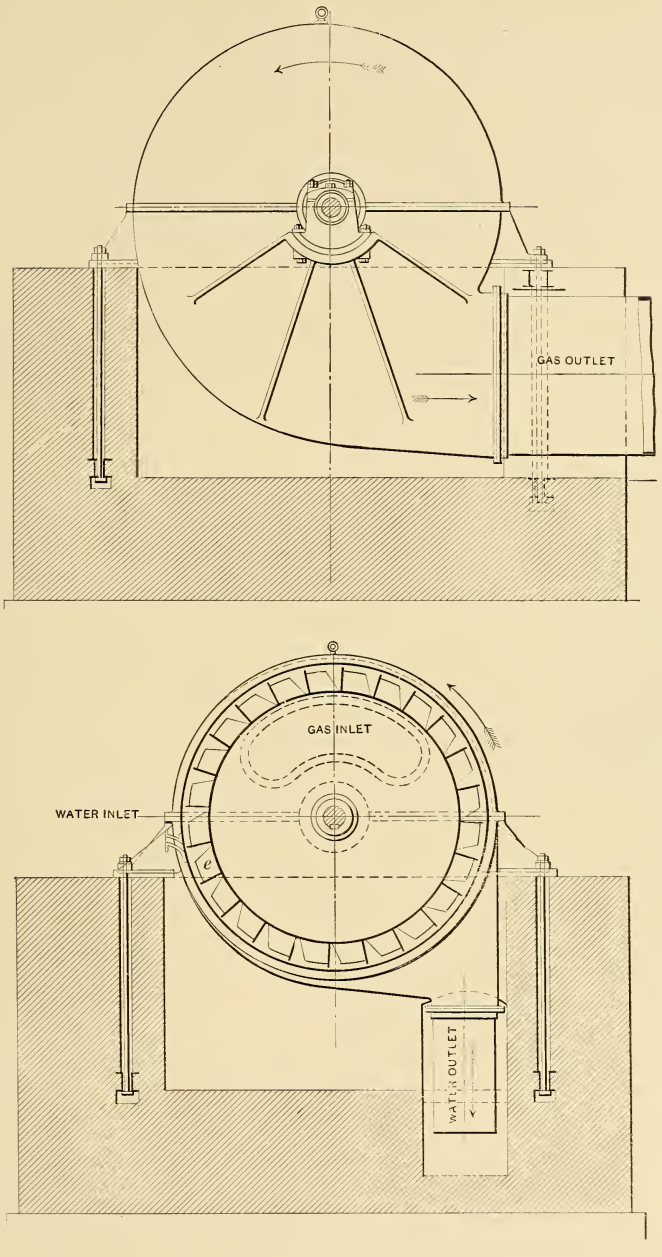
If we are not prepared, for economical or other reasons, to discard the existing steam plant and adopt gas engines, we will, however, by cleaning the gas for boilers, save about 20 per cent. of the 1,400,000 cubic feet now employed, or 280,000 cubic feet per furnace per hour. We would, therefore, liberate from stoves and boilers about 490,000 cubic feet of gas per hour, which would be sufficient for the development of from 4500 to 5000 B. H. P.

We have already pointed out the saving resulting from reduction in size of stoves, reduction in size of boiler plant, saving in delays and interruptions, and reduction in labour cost. There is another economy which is the most important of all, but which it is very difficult to express in figures,—that is, the saving which we gain by the regularity of operation of the blast furnace.

A blast furnace of the size assumed produces per day pig iron to the value of from £500 to £700. Whether this product is turned out



LONGITUDINAL VERTICAL SECTION OF A THEISSEN GAS WASHER



SECTIONS ALONG *A B* AND *C D* IN THE VIEW ON THE OPPOSITE PAGE

of high quality, in regular quantities and without interruption, or not, is therefore of supreme economical importance. An interruption of only a few hours will cause a loss of hundreds of pounds. Uniformity of all conditions affecting the blast furnace is, consequently, a requirement for successful and economical working, and by cleaning the blast-furnace gas we obtain a more effective fuel, which, in turn, creates a uniform

temperature, and a blast uniform in quantity and pressure.

As competition grows keener, possible margins of profit become smaller, and demands as to excellence and regularity of pig iron increase. Gas-cleaning plants are, therefore, certain, before long, to be as much a part of the regular equipment of a blast furnace as the hot-blast stoves are themselves, and the sooner this innovation is adopted, the sooner an annoying waste will be turned to an important economy.

UNIFORM EQUIPMENT IN ELECTRIC POWER PLANTS

By H. S. Knowlton

AMONG the striking differences in design which contrast the modern power plant with the earlier installations for the commercial production of electricity, the uniformity of present-day equipment deserves prominent mention, second only in significance to the enormous increase in the size of generating units.

Fifteen years ago a 300-KW. generator was regarded as a large machine; seven years ago a 2000-KW. unit excited the admiration of engineers from far and near; but to-day the awarding of a contract for two or three 7500-KW. outfits is regarded as a matter of course, and is within the guaranteed certainties of standard practice. The difficulties met in forging the shafts of such units—2400 per cent. larger than the machines of 1890—and the operating responsibilities of the power-house force, charged with the proper handling of single generator and engine combinations worth upwards of $150,000 to $200,000 each, are not to be passed over lightly, and yet the future will very likely witness still larger machines, probably in connection with the application of electricity to the suburban and trunk line service of steam railways operating in densely populated territory.

For a good many years far-sighted electrical engineers have been working toward that unification of equipment in the power house, which requires the generation of but two kinds of current within the station walls—direct current for the field excitation, and high-tension alternating current for the output of the plant, covering both neighbouring and distant territory through the flexibility of the stationary transformer. The day has now arrived when this can be done; but this extreme practice has been made possible only through the perfection of the alternating current enclosed arc lamp, the development of stationary single and polyphase induction motors, and the evolution of the single-phase electric railway system.

The alternating current has never lent itself to the production of electrolytic reactions, although it has become immensely valuable in heavy electric furnace work; the variable speed motor-driven machine tool still depends upon continuous current, and the direct-current railway motor refuses to be driven out of city and suburban service. For these and other reasons there will always probably be an important field of service

for direct-current power stations, and no greater mistake could be made than to assume that every new plant should be designed for alternating equipment.

A 2000-KW. direct-current 600-volt turbo-generator was recently purchased by one of the large electric street railway companies, and if this machine meets expectations in regard to operating economy, lessened attendance, low cost of maintenance and freedom from commutator troubles, it is destined to point the way toward a continuation of direct-current practice in urban centers, to say the least.

Uniformity of equipment is practically a certainty in the power plant designs of the immediate future, although in many cases both direct and alternating current are to be sold to customers. Absolutely uniform equipment means an exact duplication of generating units, and this can seldom be effected under commercial conditions. A power plant supplying a city with nothing but alternating current for public and private lighting and power can be so designed, and if the steam turbine is used in place of the reciprocating engine, the former's light-load economy will enable the plant to be operated at a high efficiency all the way from 20 per cent. load to full rated output, provided at least three units are installed.

Another case where uniform equipment is desirable is in a plant which supplies a local lighting and power load and a distant railway service with alternating current only. In a recent plant of this kind, built about six years ago, there were no less than eight station voltages,—60, 125, and 575 D.C., and 104, 350, 2300, 6600, and 13,200 A.C. The generators consisted of a 2000 KW., a 200-KW. and two 1000-KW. engine-driven alternators, and a 500-KW. turbo-alternator and two 100-KW. direct-current direct-connected generators. Two of the exciters were engine-driven; three of the alternators delivered three-phase 25-cycle current, and two, 60 cycles; a 150-KW. rotary converter for commercial power service, two two-phase alternators for lighting work, a 20-KW. motor-generator for station lighting and small motor work, and a 200-KW. synchronous motor-generator and frequency-changing set for commercial lighting and emergency power service completed the equipment.

Such a variety of apparatus is not often encountered beneath the roof of a single modern plant, and the reason for this development is found in the rapid expansion of the station's field of usefulness from a purely local lighting and power supply to the operation of sub-stations on an electric railway system covering 165 miles of track and reaching cities and towns from 30 to 40 miles away from the power house.

The advantages of uniform equipment may be summed up in the single phrase, "simplicity of operation." The larger the plant, the more desirable it is that the duties to be performed by the attendants shall be free from intricacy. Mistakes are far more costly in stations which supply groups of communities with power than in plants whose customers are numbered only in the hundreds. An error in judgment which results in the burning-out of a large power unit means a very serious expense to the operating company, and it is with these points in mind that designers are now installing so-called multiple-unit plants in which each switchboard section, generator, engine, high-pressure pipe run, and boiler group forms an essentially individual power plant.

The remote control of oil switches on the high-tension circuits and the installation of automatic synchronizers are also illustrations of the tendency toward perfecting the reliability of power stations. In the complicated layout just mentioned, the wiring is nothing short of a Chinese puzzle; high and low-tension circuits

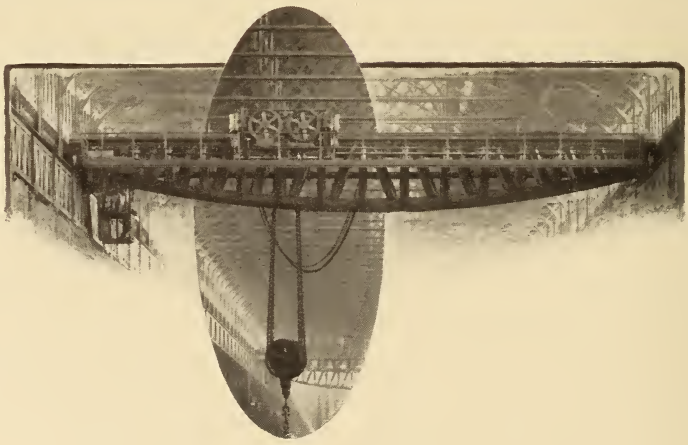
cross each other in the most promiscuous manner. It is no easy task to remember the precise usefulness of each piece of machinery, to say nothing of the switchboard apparatus. Interesting as such a station may be to the college student looking for examples in practice of a great variety of equipment, there is no question that a simpler arrangement would better conserve broad economy of operation.

With uniform equipment, repairs can be more easily and, as a rule, more quickly made; the storage of spare parts is a simple matter; and the breakdown of one unit can usually be offset to some extent by the overloading of a similar group of machines.

The question of frequency is sometimes troublesome in a plant designed for both railway and lighting service, but if worst comes to worst, motor-generators instead of rotaries can be used in the sub-stations, or a frequency changer in the power house.

There is little doubt that the use of 25-cycle machinery has often been carried too far in America, considering the successful results obtained elsewhere with higher frequencies. Many American engineers consider 60 cycles ideal for lighting work and 25 cycles indispensable for the proper operation of large rotary converters—say, from 500 KW. upward. It is somewhat strange that the use of an intermediate frequency, like 35 or 40 cycles, has not been more wisely employed in America, although the alternating-current enclosed arc lamp may be held largely responsible for this.

Concentration of power is in harmony with the centralizing tendencies of the times, and in the consolidations of the future, uniform equipment is going to play an important part in the reduction of expenses. There is little danger of going too far in this direction in new plants, but in many of the older installations it is high time to look about and see what can be done towards eliminating superfluous apparatus, or that equipment which has become obsolete through the development of better types.



RAIL MOTOR CARS IN GREAT BRITAIN

PART II.—STEAM, GASOLENE, GASOLENE-ELECTRIC, AND ELECTRIC TYPES

By J. F. Gairns

Part I, in the September Number, was devoted to a General Classification of Rail Motor Cars and Some Early Steam Car Examples

SECTION *B* differs from section *A* only in that the boiler employed is an adaptaton of the locomotive tubular type, several special designs being in use. Such cars are used on the London & South Western, Taff Vale and several other lines, and the car illustrated in Fig. 11 is one of the type employed on the Welsh lines, and designed by Mr. T. H. Riches, locomotive superintendent of the Taff Vale Railway, the builders in this case being the Avonside Engine Co., of Bristol. Vehicles of similar character are being supplied rather extensively by this firm for lines from 2-foot gauge up to the broad Colonial gauge of 5 feet 6 inches, and there are now many variations of these vehicles in use both in England and in British colonies.

The following notes furnished by the Avonside Engine Company will serve fittingly as descriptive of vehicles of this class, although the detailed practice of the various railways and builders differs somewhat:

Several types of cars have been made by some of the British railway companies with more or less success, and, after a careful study of all the types, we have decided that on the whole the car which gives the most economical results and runs the best is the car fitted with the plain locomotive boiler. One of the secrets of our great success lies in the very large proportions of actual heating surface provided, thus ensuring rapid steam generation, so that the boiler is never forced, and consequently, not only is dry steam produced, but the boiler lasts much longer. The working parts of the engine and car are exceptionally strong, and all wearing areas are very large. A great advantage possessed by our system is that the engine can be removed from the carriage portion by the use of two jacks and four men in 20 minutes, thus enabling the engine to go into the repair shops without the whole car, and saving valuable room. Where a number of cars are in use, a spare engine can be put in, and the car run again at once. The carriage underframe and bogie is specially designed to prevent rolling, and has proved so satisfactory that we have run a main-line 9-foot car backward at 45 miles per hour without any appreciable movement,—in fact, the coach rides like a first-class Pullman car.

Owing to the car being carried on two bogies, the weight per axle is reduced: lighter rails can therefore be used, and less wear and tear caused, owing to the small fixed wheel-base and easy running. The carriage portion of the car depends entirely on what class of work it is desired to do, this varying from a simple tram-car type to a most elaborate private saloon. Engineers' construction and inspection cars are also made. These are divided into a kitchen, bed-room and living-room, which enable the engineer to be quite independent of any outside assistance.

For suburban work, a car can be either wholly one class, and holding a large number of passengers, or divided into two classes with or with-

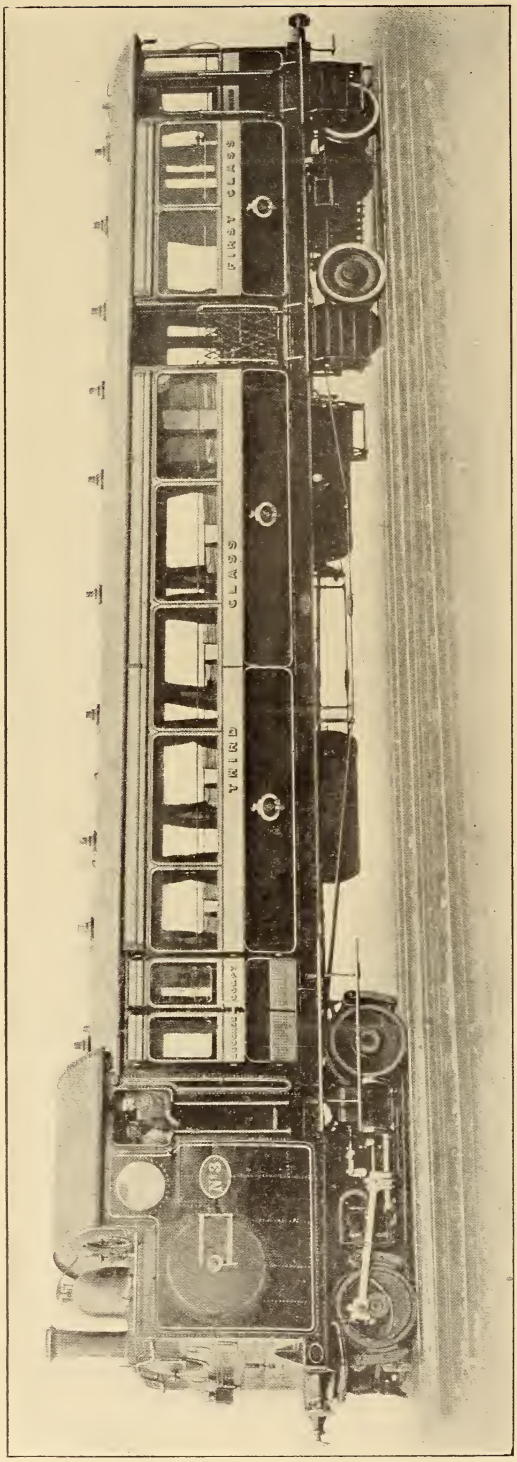


FIG. 11.—A RAIL MOTOR CAR BUILT BY THE AVONSIDE ENGINE COMPANY, BRISTOL

out luggage compartment. For colonial and foreign or branch line work, the most suitable type appears to be that divided into two classes and a luggage compartment. One or two trailers can be handled easily by any of the coupled cars, but it is not usually considered advisable to use more than one on the single-driving car unless the line is very flat.

In most British rail motor cars outside Walschaert, valve gear is employed owing to the difficulty of fitting link motion between the frames of the engine bogie, but the Taff Vale cars and the one illustrated in Fig. 11 are fitted with the ordinary gear.

Before dealing with cars having separable locomotives, it will be interesting to describe a small steam car introduced a few years ago on the Württemberg State lines in Germany. On these lines there is quite an extensive selection of rail motor cars of various kinds, there being three or four types of steam cars and several gasolene cars and electric cars. The car illustrated in Fig. 12 is a small four-wheeled one, and steam is supplied by a high-pressure boiler of Serpollet design. Vehicles of somewhat similar type are used in Austria and in Belgium; some of those used in Austria have Gölsdorf compound engines.

During the past twelve months or so there has been a marked change of opinion among British engineers, for a majority of recent designs comprise a separable locomotive and therefore belong to section *C* of our steam classification.

The first of these, that designed by Mr. J. Manson,

superintendent of the Glasgow & South Western Railway, is shown in Fig. 13. The locomotive in this case is practically a miniature tank engine, and is fitted between frame extensions of the vehicle portion so that it can be removed when necessary for repairs or other reasons. The extreme length of the vehicle is 60 feet 8 inches, and there are two passenger compartments and a rear guard's compartment, each of the former having its side door but connected by a sliding door in the division wall. Accommodation is provided for fifty passengers all of one class. At the guard's doors, folding steps are fitted to allow of entrance being effected from rail level.

Cars of similar or corresponding design are now being introduced on the South Eastern & Chatham, North Staffordshire, Great Northern, and other railways.

On the North Eastern Railway two curious rail motor cars are in use. In each case an old tank engine is permanently connected with a bogie vehicle. In one instance the vehicle is a standard tram line coach, and in the other instance it is a coach from an electric train. As the engine is never detached during work, a driver's compartment is provided at the rear end of the coach from which the driver controls the engine when running backwards.

Quite recently a number of steam rail motor cars have been introduced into American practice. As a rule, these represent a combination of locomotive and vehicle mounted on two four-wheeled bogies in similar style to those employed in British practice according to sections *A* and *B* of our classification.

A special committee was appointed last year by the officials of the Chicago, Rock Island & El Paso Railroad to report as to standard types and dimensions for locomotive stock, and their report closed with a suggested scheme for a large rail motor car for branch work which is worthy of note, as the scheme will probably be carried into practice very shortly. A large car body is mounted on two six-wheeled bogies, that at the front end having two pairs of wheels operated by a two-cylinder engine, and a small pair of leading wheels. The boiler is of a return tube locomotive type fitted with a superheater; it is located in the front engine compartment and extends into the second baggage compartment. The whole machine is 75 feet long and 10 feet wide, the accommodation being for 70 passengers.

Very little, comparatively, has been done in Great Britain, and not much

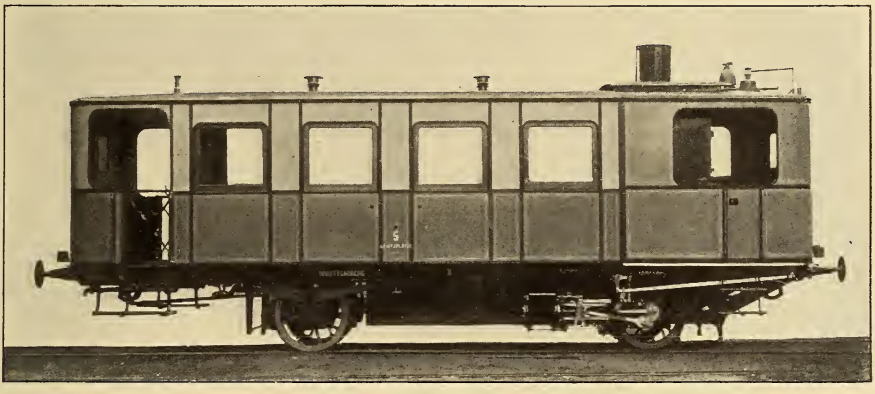


FIG. 12.—A SERPOLLET RAIL MOTOR CAR FOR THE WURTTEMBERG STATE RAILWAYS. BUILT BY THE ESSLINGEN MACHINE WORKS, ESSLINGEN

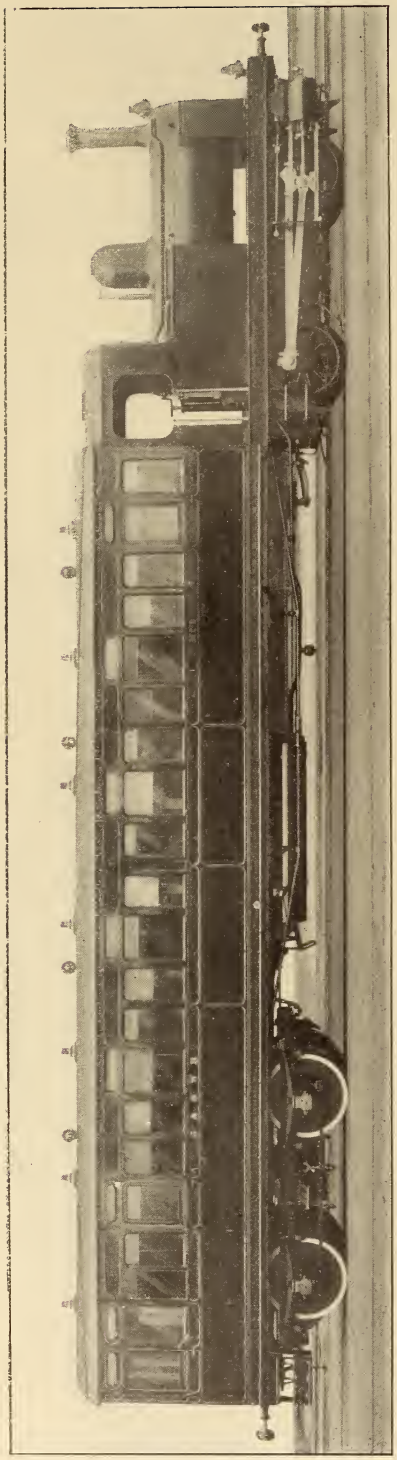


FIG. 13.—STEAM MOTOR CARRIAGE WITH SEPARATE LOCOMOTIVE FROM THE GLASGOW & SOUTH WESTERN RAILWAY. DESIGNED BY MR. JAMES MANSON, LOCOMOTIVE SUPERINTENDENT OF THE G. & S. W. R.

more elsewhere, in the use of internal-combustion or explosion (gasolene, petrol, or oil) engines for rail motor cars, and Figs. 14 and 15 show two views of the only example of this method of working in England, though it is understood that similar vehicles are under construction for the London, Brighton & South Coast Railway.

For some time past the Great Northern Railway officials have been experimenting with the petrol car illustrated, which is now employed in regular service on the Hatfield to Hertford branch. This experimental use is valuable in demonstrating the possibilities of this class of vehicles under special conditions, and is also interesting on account of new features which in many respects constitute a distinct advance in this type of car. The car has been specially designed by Messrs. Dick, Kerr & Co., Ltd., of London, and in evolving it they have been able to utilize their extensive experience in electric tram car construction. The system of applying two electric motors to a tram car has been copied in the automobile, two petrol engines being employed, which are connected to a shaft in a manner that will be described.

The seating capacity of this car is for 32 passengers, but this can be considerably increased, and the firm in question is already engaged on a larger type of car which will not only carry many more passengers but will also provide a certain amount of space for luggage.

The whole of the machinery is assembled upon a frame directly supported from the axles. It is thus entirely isolated from the body of the coach, with the consequence that even while standing at a station the noise and vibration from the engines are almost imperceptible to the passengers.

As already indicated, following the practice now generally employed in electrically driven cars, the motive power consists of two engines, which

FIG. 14.—A PETROL RAIL MOTOR CAR FOR THE GREAT NORTHERN RAILWAY. BUILT BY MESSRS. DICK, KERR & CO., LTD., LONDON

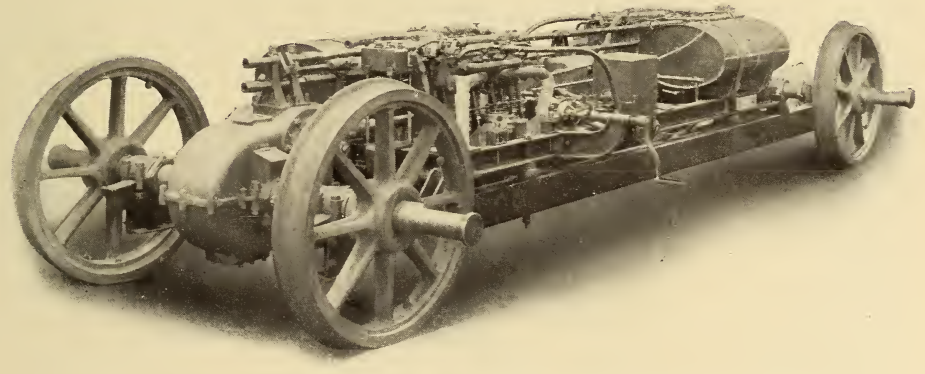


FIG. 15.—THE UNDERFRAME AND ENGINES FOR THE PETROL CAR SHOWN IN FIG. 14

not only minimizes the risk of breakdown but gives a better distribution of weight. The engines are not, however, connected independently to the axles, although both axles are driven, but under normal circumstances drive on to a common longitudinal shaft which is connected to the axles by beveled gearing. To overcome the difficulty of one axle overrunning the other, owing to any possible inequality in the diameter of the wheels, a special form of differential gear is introduced, and combined with this special gear is the reversing mechanism.

The engines are connected through independent clutches to a common change-speed box, from which the power is transmitted by means of the longitudinal driving shaft previously mentioned, into gear boxes suspended on each axle; at this point the engine speed is reduced as required on the axles by means of single reduction gearing very similar to that used in electric tramway cars. The engines are of the standard Daimler

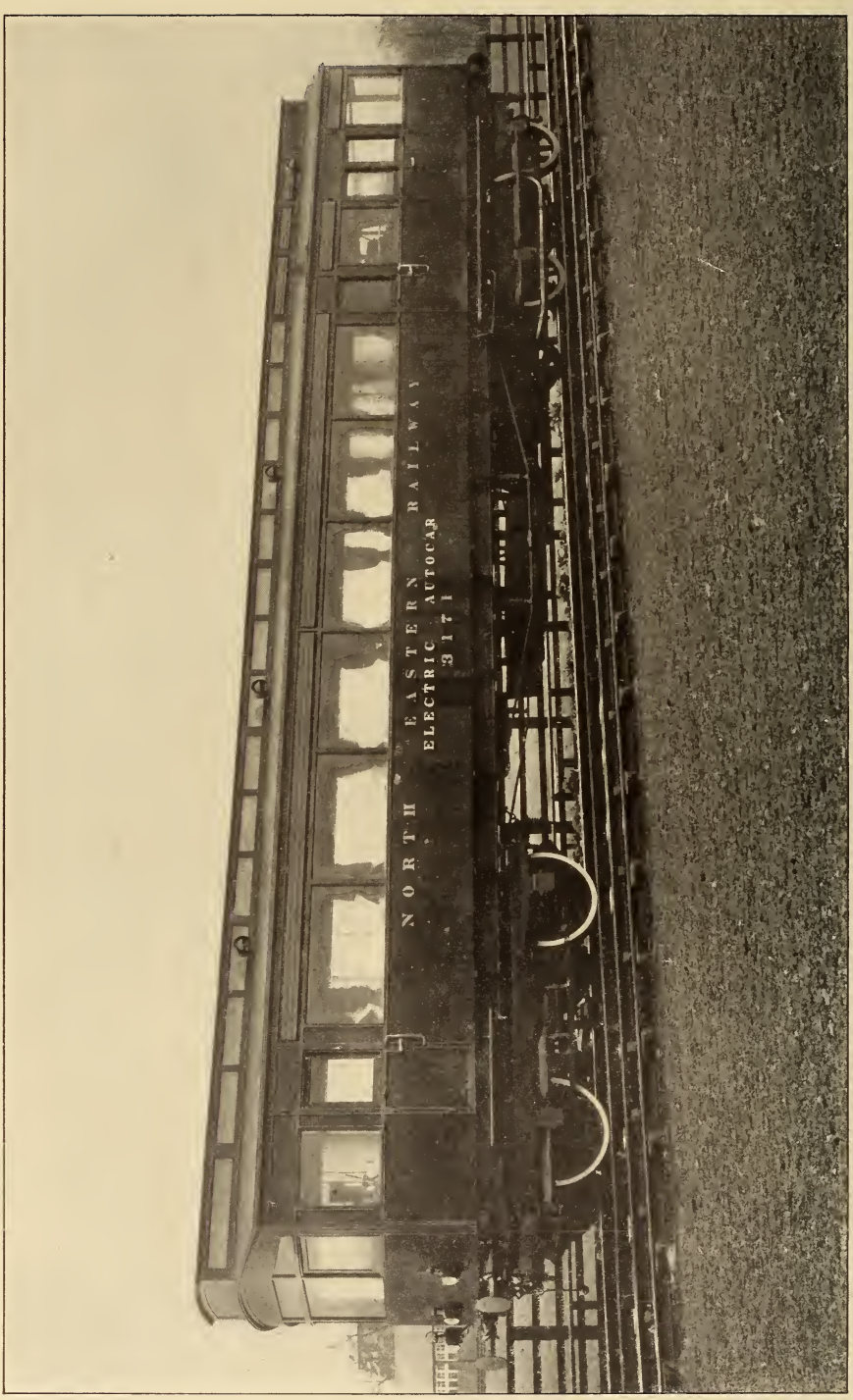


FIG. 16.—A PETROL-ELECTRIC RAIL MOTOR CAR FOR THE NORTHERN RAILWAY, EQUIPPED WITH AN 80-B. H. P., FOUR-CYLINDER, HORIZONTAL PETROL MOTOR MADE BY THE WOLSELEY TOOL & MOTOR CAR CO., LTD., OF BIRMINGHAM

FIG. 17.—A RAIL MOTOR CAR OPERATED BY A SIX-CYLINDER GASOLENE ENGINE MADE BY THE STANDARD MOTOR WORKS, JERSEY CITY, N. J. THE CAR WAS BUILT AT THE SHOPS OF THE UNION PACIFIC RAILROAD

type, each capable of developing 36 H. P. when running at full speed. A separate petrol tank is provided for each engine, and the combined capacity of these is equal to 400 car-miles.

The car complete weighs less than 16 tons, including its full complement of passengers, and although the normal speed for which it is designed is 30 miles per hour, it has on several occasions attained a speed considerably over 50 miles. The car is lighted by electricity ob-

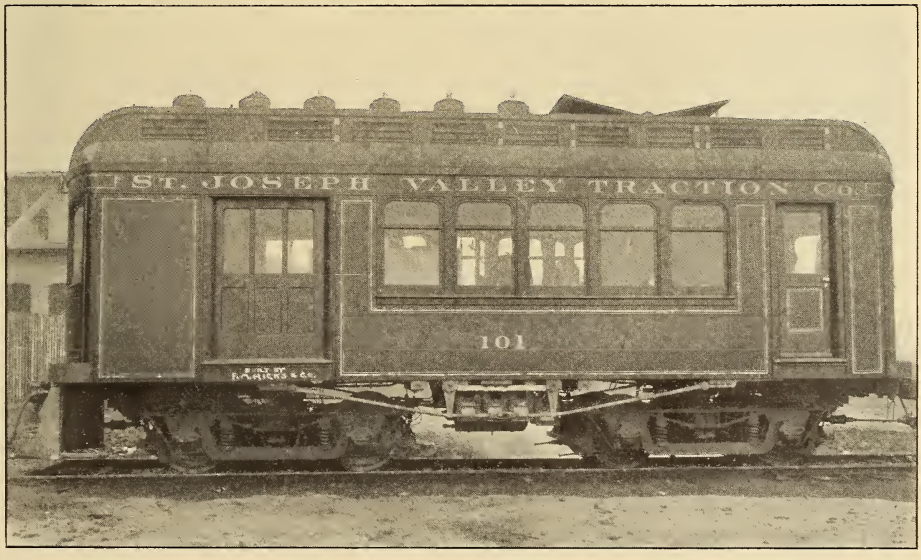


FIG. 18.—A GASOLENE-ELECTRIC MOTOR CAR FOR THE ST. JOSEPH VALLEY TRACTION CO. BUILT BY MESSRS. F. M. HICKS & CO., CHICAGO

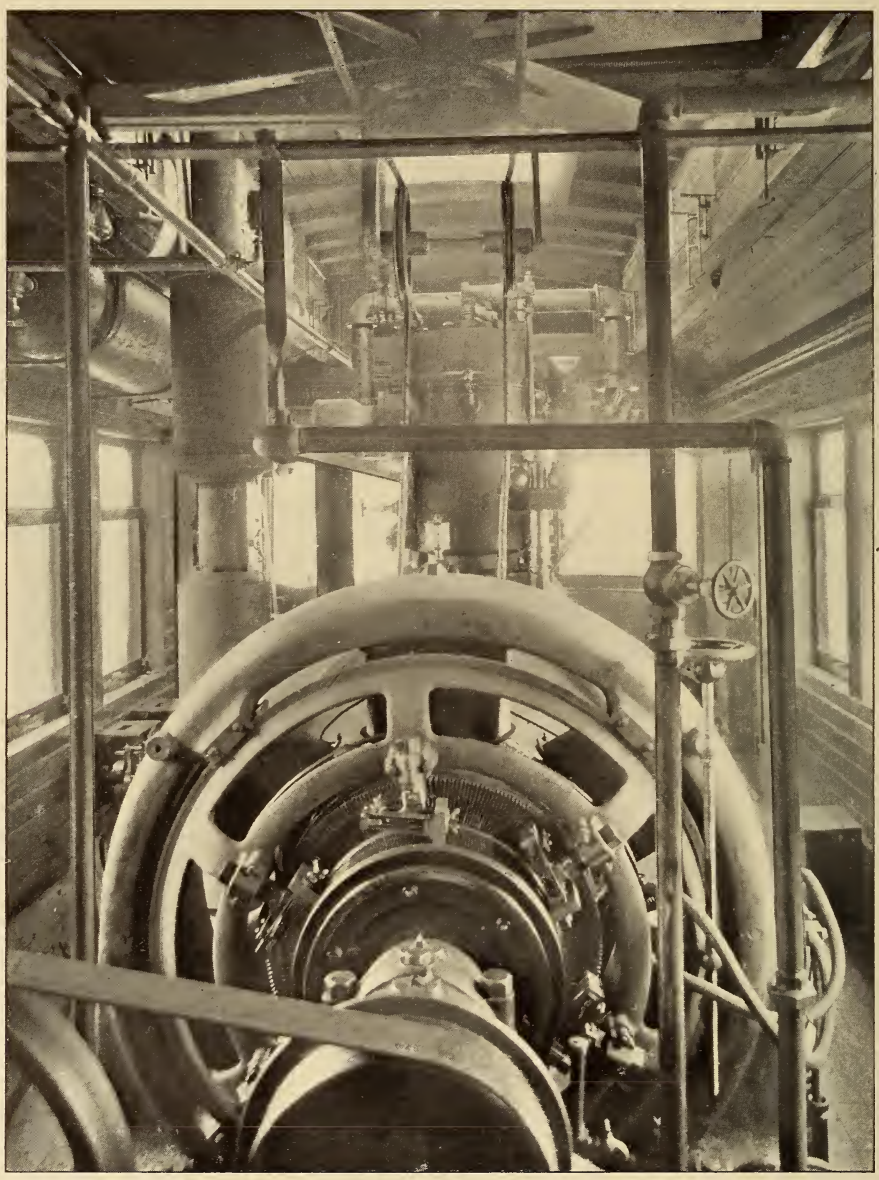


FIG. 19.—ENGINE COMPARTMENT OF THE GASOLENE-ELECTRIC MOTOR CAR SHOWN IN FIG. 18

tained from storage batteries, which also supply current for the ignition and the magnetic clutches. The design of the complete car is such that by jacking up the body, the underframe and machinery can be run out in the same manner that a truck can be taken from beneath a standard electric tramway car, but in addition to this, the frame containing the machinery can be dropped from its bearings on the axles without removing the truck from underneath the car body, so it will be seen that the flexibility and facilities for overhauling and repairs are everything that can be desired. As has already been stated, the engines in this case

are made by the Daimler Motor Co., of Coventry, who have also manufactured the greater portion of the transmission gear to the order of Messrs. Dick, Kerr & Co.

The design of the car and its experimental operation has been under the personal supervision of Mr. Oliver Bury, the general manager of the Great Northern Railway Company. The illustrations show, respectively, the complete car in use, and the framing with the body removed, exposing the engines and mechanism.

The gasolene-operated car is receiving considerable attention in the United States, and an interesting vehicle of this type recently supplied to the Union Pacific Railroad is shown in Fig. 17. In contrast with most other rail motor cars, this vehicle is designed for high speeds, hence the prow-shaped front and rounded rear end to minimize air resistance. A six-cylinder gasolene engine made by the Standard Motor Works, Jersey City, N. J., of the design introduced for racing motor boats, is fitted, and is adapted to the requirements of the situation. Gearing is employed for transmission, and is arranged so that the engines can be easily started free and the load picked up. A number of special fittings are employed for this car, but these cannot be dealt with here for lack of space. Its seating capacity is 25, and the car was built at the railroad shops, being designed by Mr. W. R. McKeen, Jr., superintendent of motive power and machinery.

In several quarters the gasolene-electric system of propulsion for rail motor vehicles is finding considerable favour, though it is only a few years since that Mons. Heilmann's locomotive, in which a steam engine operated a dynamo in similar fashion and which was extensively experimented with on the Western Railway of France, was described as a locomotive freak and as representing an extravagant method of working. Yet a car operated on this double-conversion principle has been running for about two years on the North Eastern Railway of England, and several more will shortly be introduced abroad, while in the United States a number of similar cars are on order.

Fig. 16 illustrates the North Eastern car by exterior and interior views. The engine compartment, at the front, contains a "Wolseley" 80 B. H. P., four-cylinder horizontal petrol motor supplied by the Wolseley Tool & Motor Car Co., Ltd., of Birmingham, the engine cylinders and valve boxes being water-cooled; the car can be controlled with equal facility from either end.

The petrol motor is direct coupled

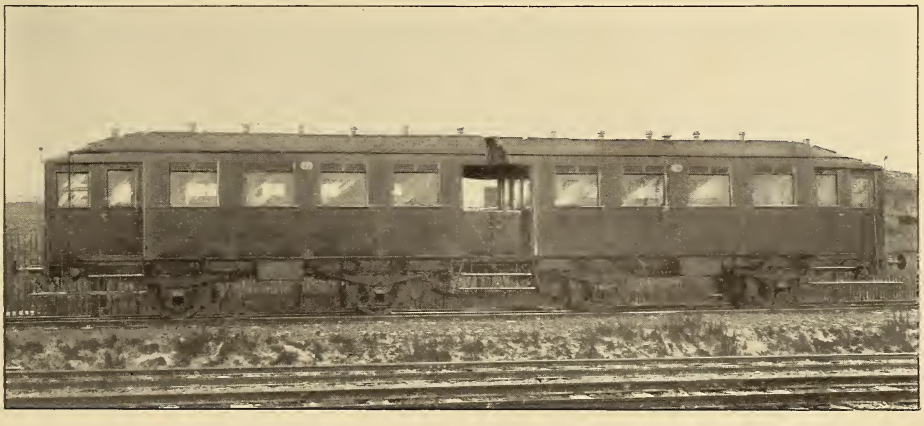


FIG 20.—AN ACCUMULATOR-ELECTRIC RAIL MOTOR CAR FOR THE SAXONY STATE RAILWAYS BUILT BY THE SAXON WAGON WORKS, WERDAU

FIG. 21.—A RAIL MOTOR CAR BUILT BY MONSIEUR VALENTIN PURREY, BORDEAUX, FOR THE PARIS-ORLEANS RAILWAY

to the generator, which operates at a normal speed of 420 revolutions per minute. The electric current thus produced passes from the generator through an automatic circuit-breaker to two controllers, from whence it is applied to two motors mounted on the front bogie underneath the car. The two motors are of the standard type usually employed for operating heavy, high-speed tram cars, and the car is started when the voltage of the generator is adjusted to 400, which is gradually increased to 550, when the car quickly attains a constant speed of 36 miles per hour.

The electric brake is so constructed that it does not depend upon the generator plant for the supply of power, and is therefore perfectly reliable. An air compressor driven by a 1-H. P. electric motor is fixed on the rear bogie to supply the air for the alarm whistle and the brakes, and there is an automatic arrangement for maintaining a constant pressure in the air reservoir. The weight of the car, in full working order, is 35 tons; it carries a supply of fuel and water for a full day's work, and can be put into service at ten minutes' notice.

Figs. 18 and 19 illustrate, respectively, an exterior view and a view of the engine compartment of a gasolene-electric rail motor car recently supplied by Messrs. F. M. Hicks & Co., of Chicago, for the St. Joseph Valley Traction Company. This car, unlike those previously described, is not intended for passenger service, but is used for hauling baggage traffic. It comprises two compartments, one containing the engine, generator, storage cells, etc., and the other accommodates a considerable amount of baggage. Usually, too, a trailer baggage van is hauled in addition.

The length of the car is 34 feet, its width is 9 feet 8 inches, and its extreme height is 14 feet. The engine is a four-cylinder, gasolene motor built by the Marinette Gas Engine Company of Chicago, and is designed to develop about 70 H. P. when running at 325 revolutions per minute. It is direct connected to a 50-KW. 250-volt generator built by the Sprague Electric Company, New York, and supplies current to four 35-H. P. motors on the trucks. A battery of 120 chloride accumulator cells connected in series assists during acceleration.

An air compressor is belted to the generator and maintains a pressure of 200 pounds per square inch, and usually the engine is started by means of compressed air until it gets into proper working stride. The generator also supplies current for lighting, for ignition, and for a 4-H. P. motor compressor used for air brakes. The car can be controlled from either end, duplicate controllers, etc., being provided in the baggage compartment. The following particulars supplied by the railway company as to practical use with this car will be of interest:—

"This car has been in actual service since March 30, and has made from two to three 22-mile trips daily, hauling a 45-foot trailer. Every part of the car seems to work perfectly satisfactorily. The cost of fuel per mile averages 76-100 gallons of gasolene. The heaviest grade is 1 per cent. on the main line, but at one place there is a short 4 per cent. grade on a 34-degree curve, and the car goes up this grade without any trouble whatever."

As regards the direct employment of electric power for rail motor cars, very little has been done of late, though a number of experimental cars were tried many years ago, and others have appeared at intervals. A recent rail motor car operated electrically from accumulators, however, is shown in Fig. 20, this car being one introduced on the Saxony State railways some time ago, the builders being the Saxon Wagon Works, of Werdau.

The car is in two sections pivotally connected, each section running on four wheels, and each of the four

STORAGE BATTERY LOCOMOTIVE BUILT FOR THE UNDERGROUND ELECTRIC RAILWAYS CO., LTD., OF LONDON, BY MESSRS. HURST, NELSON & CO., LTD., MOTHERWELL.

axles being operated by its own electric motor. Current is supplied at 365 volts by 184 accumulator cells distributed under the seats of the vehicle. The seats are arranged longitudinally at the sides and along the center, so that a large number of passengers can be accommodated. The car can be controlled from either end.

From the foregoing it will be seen that much engineering interest attaches to the design of rail motor cars, and that there is considerable variety in the world's practice. At present, Great Britain is far ahead of other countries in the matter of the employment of rail motor cars, and there is considerable uniformity in practice, nearly all the vehicles there introduced being operated by steam, while the work done in other countries is more experimental. At the same time it must be remembered that only representative examples of practice have been dealt with, and probably every country of importance can supply material for a separate article on this interesting subject, the writer's purpose being to review practice rather than to exhaustively deal with any one section or the work of any one country.

In conclusion, the writer would acknowledge his indebtedness to the officials of some of the railways mentioned, and from the firms whose productions are dealt with in detail.

The rail motor car shown in Fig. 21 is a good example of French practice. It represents a car supplied by M. Valentin Purrey, of Bordeaux, who has built a number of such vehicles for several French, Italian and Portuguese railways, the car illustrated being in service on the Paris-Orleans Railway.

The motor car comprises three sections—the engine compartment, a postal and baggage compartment, and a first-class compartment. A trailer vehicle is hauled for third-class passengers. The length of the motor vehicle over buffers is 43 feet. The car is supported by a four-wheeled bogie driven by the engine, with wheels 3 feet 5 inches in diameter, and a single pair of rear carrying wheels. The first-class compartment accommodates 21 passengers; five can be carried on the rear platform. The weight of the vehicle is 27 tons in working order. The boiler is of special design, and contains 280 square feet of heating surface; the grate area is 9 square feet. Coke is used as fuel. The engine is a four-cylinder tandem-compound, and drives the axles through gearing. A special superheating apparatus is employed. The vehicle is guaranteed to be able to ascend a grade of 1 in 50 at a speed of 37 miles an hour with a trailing load of 17 tons, while on a level a speed of from 60 to 65 miles an hour can be maintained. Orders have been recently given for numerous new vehicles of Monsieur Purrey's design by several French and other railways.

AN INDUSTRIAL COMPRESSED-AIR RAILWAY

COMPRESSED AIR LOCOMOTIVES IN THE ANACONDA COPPER MINING COMPANY'S NEW REDUCTION WORKS AT ANACONDA, MONTANA, U. S. A.

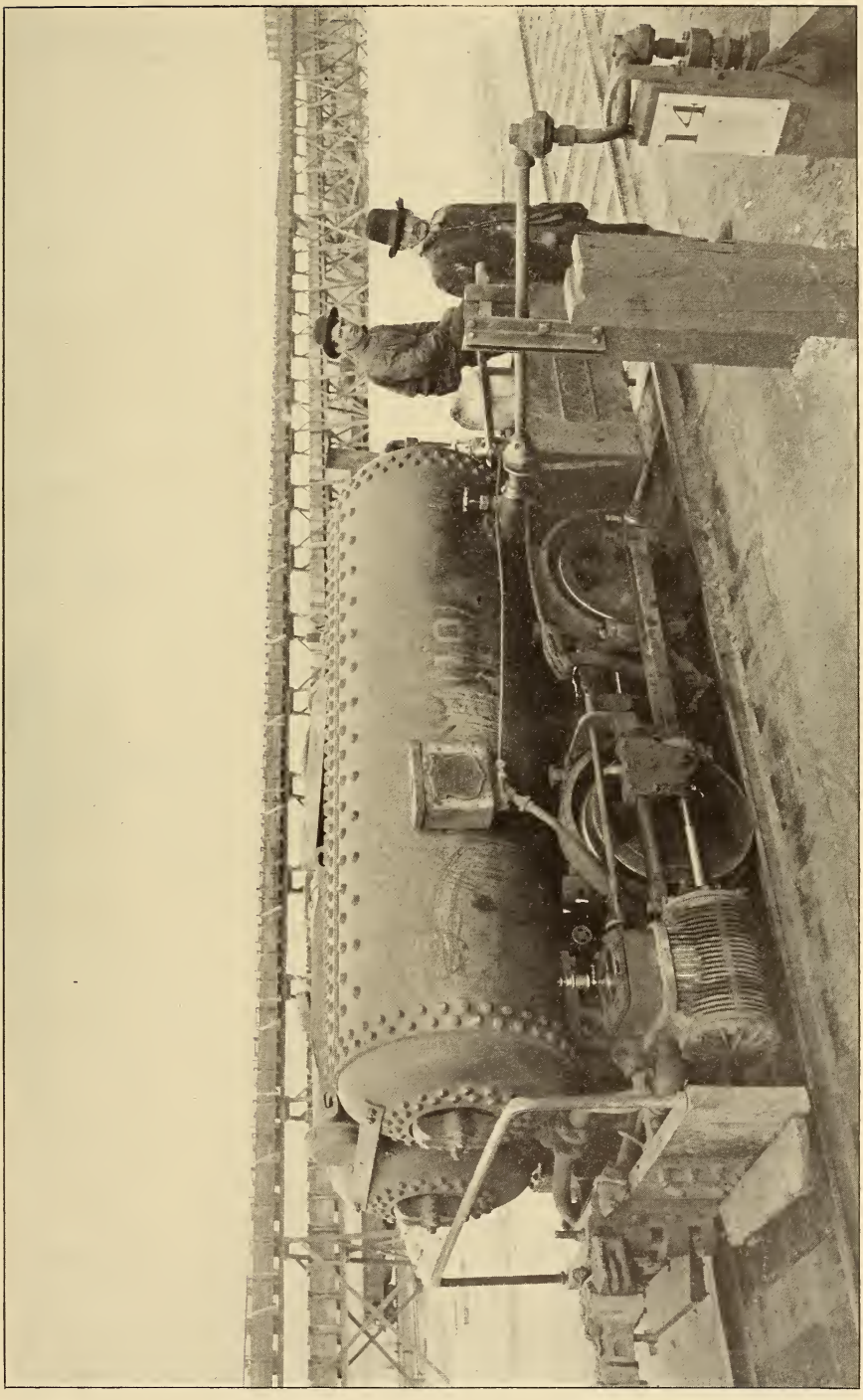
By C. B. Hodges

IN May, 1905, the writer became indebted to Mr. E. P. Matthewson, manager of the Anaconda Copper Mining Company's new reduction works, for opportunities offered to study their rather novel compressed air system of transportation. Compressed air locomotives are used at these works more extensively and continuously than at any other mine or works in the world. The Anaconda reduction works are operated twenty-four hours per day, and seven days in the week.

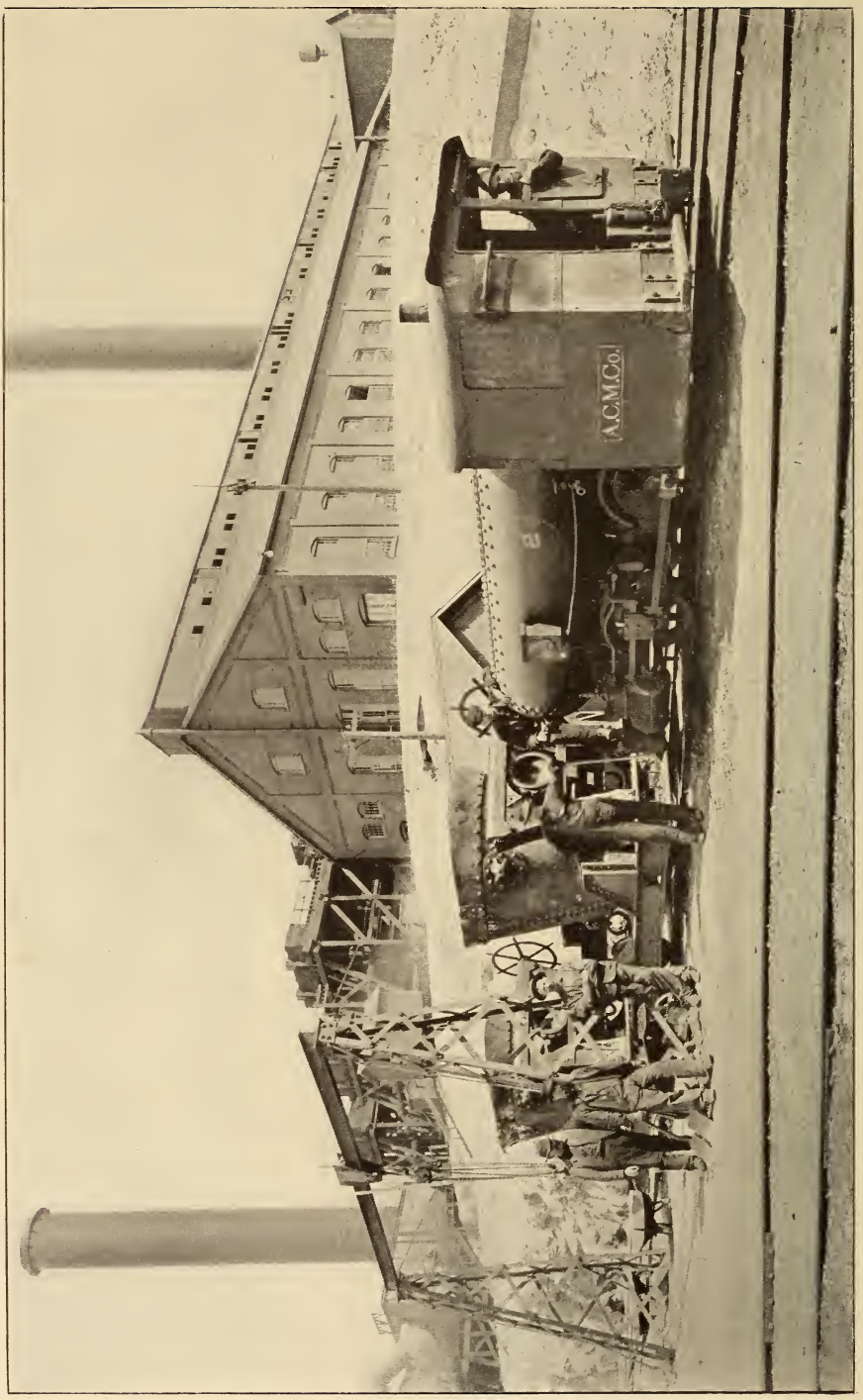
The company works eleven or twelve compressed air locomotives for sixteen hours each day, and nine for the remaining eight hours. It owns thirteen locomotives, as under the conditions practically continuous work is essential, and a spare locomotive is required in order that necessary repairs may be made. Twelve of these locomotives weigh 26,000 pounds each, have cylinders 9½ inches in diameter by 14-inch stroke; driving wheels 28 inches in diameter; a rigid wheelbase of 54 inches; main storage tanks of 132 cubic feet capacity; tractive force 5700 pounds. The remaining locomotive weighs 42,000 pounds, has cylinders 12 inches in diameter by 18 inches stroke; driving wheels 36 inches in diameter; a rigid wheelbase of 60 inches; main storage tanks of 218 cubic feet capacity; tractive force 9180 pounds.

The main storage tanks are charged, at intervals of from twenty minutes to one hour, with air at a pressure of from 700 to 800 pounds per square inch, which is then reduced to a pressure of about 150 pounds for use in the cylinders of the locomotives. When the pressure in the main storage tanks, as shown by a gauge facing the engineer, has dropped to a point near 150 pounds per square inch, the locomotive is stopped at the next charging station and recharged, this operation of recharging taking from one to two minutes.

The machinery on these locomotives is in most respects the same as would be employed on a steam locomotive of the same size, the chief difference being that the cylinders are ribbed, in order that they may the more rapidly absorb heat from the atmosphere, instead of being lagged to prevent the loss of heat, as is the case with steam locomotives. The compressed air goes into the main storage tanks on the lo-



A LOCOMOTIVE BEING CHARGED WITH AIR. THE ENTIRE OPERATION OF COUPLING, CHARGING, AND UNCOUPLING IS FREQUENTLY PERFORMED IN LESS THAN A MINUTE AND A HALF. ALL THE COMPRESSED AIR LOCOMOTIVES CONSIDERED IN THIS ARTICLE WERE BUILT BY THE H. K. PORTER CO., PITTSBURGH, PA.



A HOT-METAL TRAIN OF LADLE CARS AT SCALES WHERE THE METAL IS WEIGHED

comotives at atmospheric temperature, and falls to a temperature far below that of the atmosphere during the expansion in the cylinders. This feature has an important bearing upon the relative efficiencies of the three great powers,—steam, electricity and compressed air, under certain conditions.

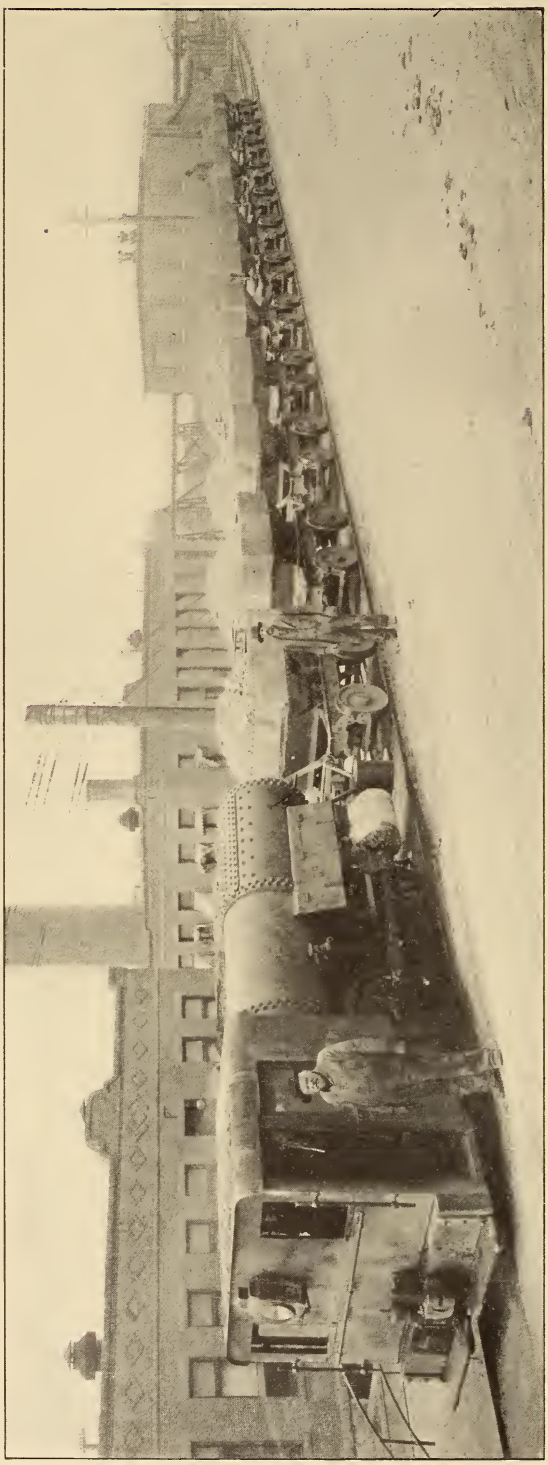
An electric motor is an inefficient machine while coming up to normal speed; a steam engine is inefficient until the walls of the cylinders are thoroughly heated; but a compressed air engine is most efficient, thermodynamically, with the first movement of the piston, because the walls of the cylinders are then at their highest temperature. This fact would point to the use of compressed air locomotives wherever stops and starts are to occur with great frequency. The main storage tanks on the air locomotives replace the boiler, and need but little description. They are exceptionally good pieces of work, having required no repairs during four years of service; they are to-day practically bottle-tight. The locomotives stand for hours without perceptible loss of pressure.

The regulating valves on the locomotives deserve special attention. To make the locomotives successful, this piece of apparatus must at all times maintain, with the minimum amount of attention, a practically uniform pressure in the small auxiliary reservoir located between the regulating valve and the throttle valve, and be absolutely tight when the locomotive is at rest. How well the regulating valves on these locomotives perform is evident to anyone who rides on them. The gauge-hand that indicates the pressure in the auxiliary reservoir is apparently glued to the 150-pound mark on the gauge while the locomotive is in motion, and it seldom rises above 175 pounds while the locomotive is at rest.

The compressed air required by the locomotives is furnished by two compressors, having cross-compound steam cylinders equipped with Corliss valve-gear, and four-stage air cylinders. The compressors are duplicates. The high-pressure steam cylinder is 20 inches, and the low-pressure steam cylinder, 40 inches in diameter; all air cylinders are single-acting; the intake air cylinder is $37\frac{1}{4}$ inches in diameter, first intermediate cylinder $20\frac{1}{4}$ inches, second intermediate cylinder $12\frac{1}{2}$ inches, high-pressure cylinder 6 inches, and the common stroke is 48 inches. The intake and first intermediate cylinders are placed behind one steam cylinder; the second intermediate and high-pressure cylinders behind the other. All the air cylinders are water-jacketed, and intercoolers are provided for cooling the air after each stage of compression.

The compressors are equipped with automatic speed and pressure governors, and an examination of the sheets taken from the recording gauge shows that the regulation of pressure is absolutely perfect. They are operated with steam at 150 pounds pressure and with a vacuum of 17 inches in the condenser, perfect vacuum at the elevation being 24 inches. The rated speed is 70 revolutions per minute; the horse-power developed per revolution, 8.7; the steam consumption per horse-power-hour when operating at a speed of 55 revolutions per minute, 18.67 pounds. The company intends to improve the vacuum in the near future, which will undoubtedly result in a lower steam consumption.

The remainder of the haulage equipment consists of a system of piping varying in size from 2 to 6 inches. This serves two purposes:—First, it connects the compressors with the various charging stations; second, it provides a reservoir containing a reserve supply of compressed air at a pressure in excess of that required by the locomotives, and sufficient to charge one or two locomotives instantaneously. Although this pipe line sustains a pressure of 950 pounds per square inch and con-



TRAIN CARRYING COARSE CONCENTRATES. THE LOCOMOTIVE WEIGHS 42,000 POUNDS, AND TRAVELS 14,000 FEET IN MAKING ONE ROUND TRIP. BOTH LOCOMOTIVE AND TRAIN ARE EQUIPPED WITH WESTINGHOUSE AIR BRAKES

sists of several thousand feet of pipe of various sizes, with many branches, valves, and charging station connections, leaks are extremely rare and it requires a rather tedious search to discover one. The losses due to this cause must be small indeed, as a leak of any importance is readily heard by any person within a radius of 10 feet.

The compressed air locomotives are operated over about 18 miles of standard gauge track laid with 60-pound rails, located inside of an irregular area about half a mile square. The reduction works are located on a side hill, and the locomotives, in doing their varied work, pass from the bottom of one building to the top of another, under the dripping bins from which the concentrates are drawn, and over, under and around the furnaces, in an atmosphere of heat, dust and sulphurous acid, with sharp curves, steep grades, and loads that tax their capacity to the extreme limit.

Outside the buildings the locomotives are subjected to extremes of weather. At an elevation of 5000 feet above sea level, at Anaconda, Mont., the range of temperature is from 95 degrees above zero to 35 degrees below, with heavy snows and high

PERFORMANCE OF COMPRESSED AIR LOCOMOTINES

Number of Locomotives	MATERIAL	Quantity in Net Tons	Weight in Lbs. of Empty Car.	Average Weight in Lbs. of Load on Each Car	Number of Cars Per Train	Number of Trains Per Shift	Number of Shifts Worked	Distance in Feet
1	Coarse concentrates, first-class ore, converter lining, and lime rock.....	1200.	7,500	16,666	12	6	2	7,000
1	Fine concentrates.....	1746.54	6,400	18,192	6	10 or 11	3	2,000
1	Coal.....	360.	6,200	6,545	6 or 7	5 or 6	3	3,400
2	Calcines.....	1450.	6,500	10,175	3	32	3	1,500
1	Hot metal.....	731.42	23,200	19,505	1 or 2 seldom 3	13 to 15	3	1,800
3	Coarse concentrates, flue dust, first-class ore, clay and lime rock.....	3600.	4,200	4,286	2 trains 16 cars 1 train 20 cars	33	3	1,600
1	Miscellaneous.....	1400.	32,000	53,000	1 or 2	13	3	1,000
1	Miscellaneous.....	950.	6,400	9,000	1 to 20	12	2	1,000
	Total.....	11,437.96						

	MATERIAL	Grade	From	To	See Note	Ton-Miles Exclusive of Locomotives Net	Gross
1	Coarse concentrates, first-class ore, converter lining, and lime rock.....	2% F. L.*	Upper part concentrator	Stock bins	A	2,120	4,027
1	Fine concentrates.....	1% A. L.†	Lower part concentrator	Roaster building	..	662	1,127
1	Coal.....	Level	Stock bins	Reverberatory furnaces	..	232	671
2	Calcines.....	Level	Roaster	Reverberatory furnaces	..	412	938
1	Hot metal.....	Level	Reverberatory and blast furnaces	Converter	B	207	684
3	Coarse concentrates, flue dust, first-class ore, clay and lime rock.....	Level and 2½% A. L.†	Stock bins and brick plant	Blast furnaces	C	1,090	3,225
1	Miscellaneous.....		Between all points.....		D	267	581
1	Miscellaneous.....		Between all points.....		D	140	340
	Total.....					5,170	11,593

NOTE A.—A 42,000-pound locomotive. This locomotive also shifts 5 or 6 standard railroad cars per day, and also 1 large wood car per day, equivalent to about 2 more round trips per shift.

NOTE B.—Each round trip includes trip through Y for cleaning ladle and three weighings.

NOTE C.—Each round trip includes side trips to various locations under stock bins and to brick plant, then to blast furnaces.

NOTE D.—Miscellaneous shifting of standard railroad cars and plant cars, handled by both locomotives. This work is roughly estimated.

*In favour of loads. †Against loads.

winds. Under these conditions the records of the company show that the compressed air locomotives, during the months of January, February and March, 1905, lost $5\frac{3}{4}$ hours for one locomotive out of a total of 22,320 locomotive-hours, distributed among thirteen locomotives. These records show all delays chargeable to failures of the transportation system and are kept with great exactness.

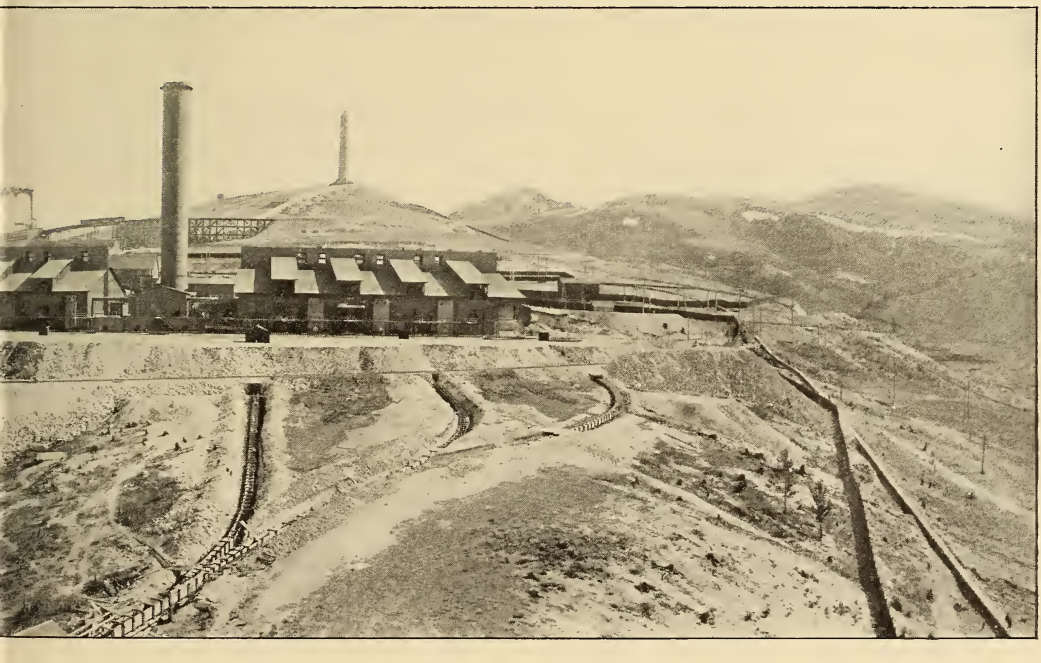
The new reduction works were first operated in February, 1902. The locomotives in question have been the only means of internal transportation since the first pound of copper was produced, and the nine original locomotives, purchased in November, 1900, which were used during construction, are still in service and apparently as good as new, except for the necessity for regular running repairs. The tabulated data on this page give a rough idea of the work which is being performed.

It should be understood in reviewing the table that it does not by any means represent all the work done by the locomotives. The first omission is the movement of the locomotives themselves, both when hauling trains and when running light from point to point; second, the endless "spotting" and shifting that is necessary in order to weigh, load, and unload the material hauled. For example, in the case of the locomotive hauling hot metal, the cars or ladles must be spotted for weighing three times on each round trip, in addition to three other stops,—two for loading and un-

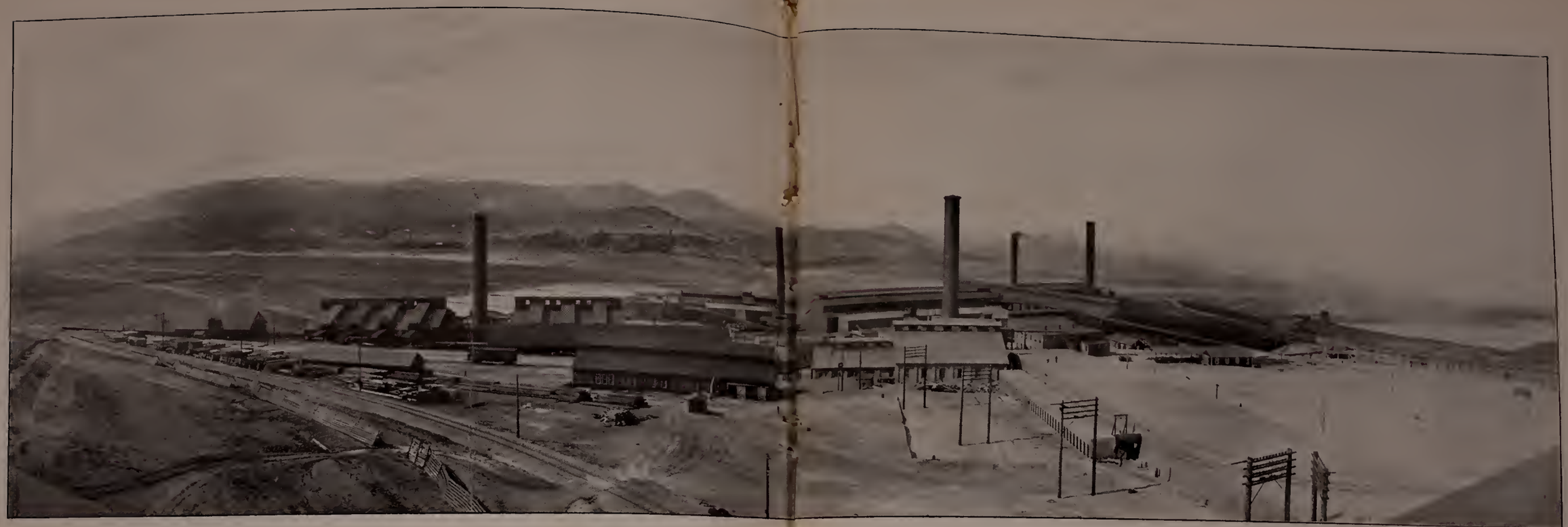
A GENERAL VIEW OF THE ANACONDA COPPER MINING COMPANY'S NEW

LOOKING

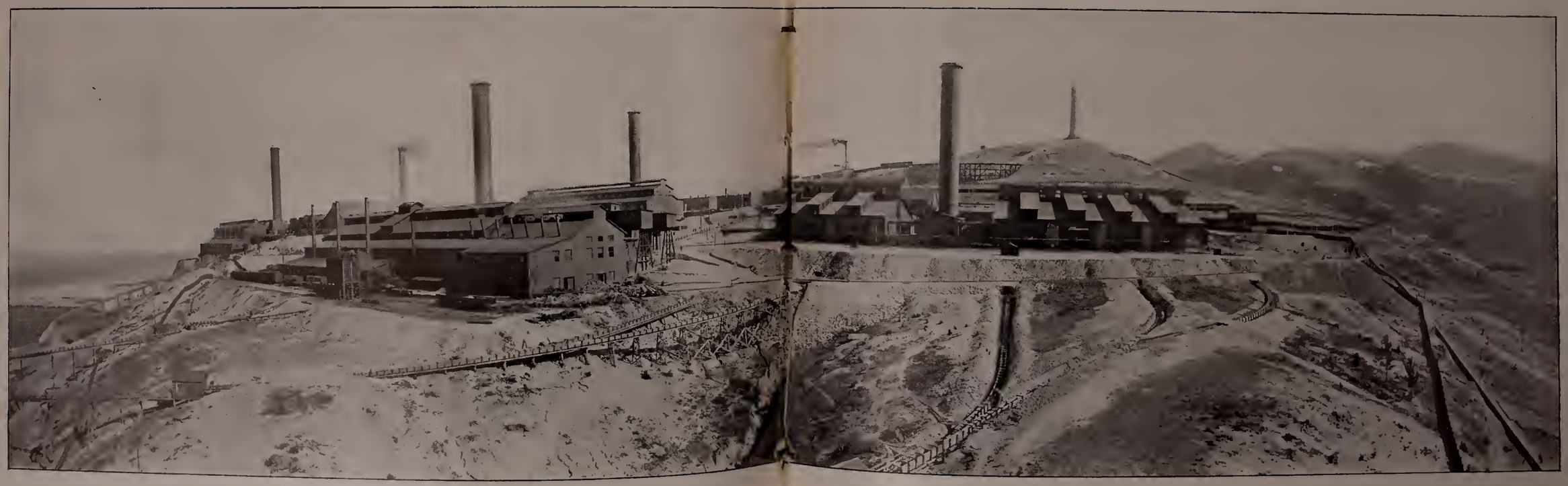
DUCTION-WORKS AT ANACONDA, MONTANA, U. S. A. LOOKING NORTH



SOUTH



A GENERAL VIEW OF THE ANACONDA COPPER MINING COMPANY'S NEW REDUCTION-WORKS AT ANACONDA, MONTANA, U. S. A. LOOKING NORTH



LOOKING SOUTH

TWO 26,000-POUND LOCOMOTIVES HAULING A TRAIN OF BOX CARS, LOADED WITH COKE, TO THE BLAST FURNACE

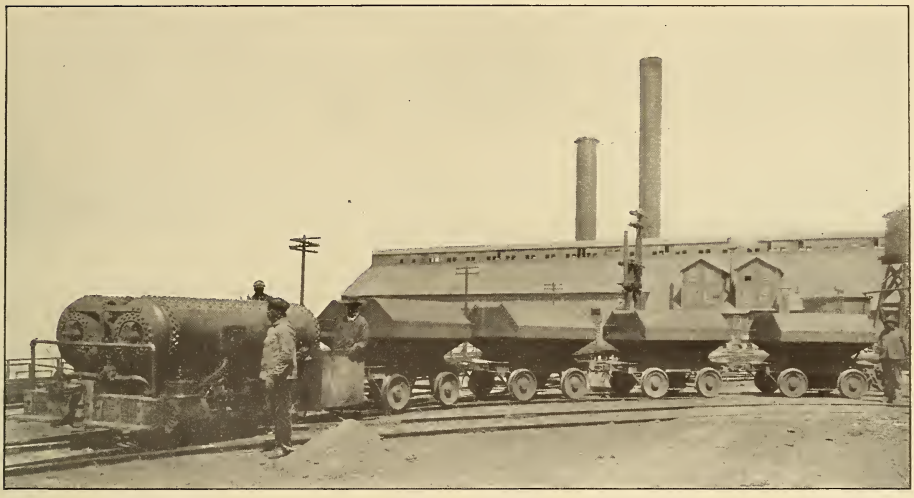
loading, and the third for cleaning the ladle, this latter operation being performed on a spur leading off a *Y*.

In the case of the three locomotives hauling coarse concentrates, first-class ore, flue dust, slag, and limestone from the stock bins and brick plant to the blast furnaces, each carload must contain its proper proportion of each of the various ingredients, and each car must be "spotted" under the proper chute and weighed after each class of material is put in. At the other end, the train of from sixteen to twenty cars is moved back and forth eight or ten times in placing the various cars so that they can be unloaded in the proper place, in the proper furnace. Even the easiest runs involve at least two weighings of the train—one loaded and the other empty—and several shifts to place the cars at the proper points for loading and unloading. All this is necessary in order that the efficiency of the various operations may be traced at all times.

Samples of crude ore, concentrates, calcines, slags, flue dust and the metallic product of the blast and reverberatory furnaces, together with the black copper from the converter, are taken daily and analyzed. This combination of systematic weighing of all materials after every process, with daily sampling and analyses, enables the management to detect and stop promptly any unusual losses in the process.

To do this work, locomotives were required that were self-contained, reliable, powerful, smokeless, compact, and simple in operation. With steam locomotives the smoke and steam in the tunnels under the bins and furnaces would have made it almost impossible for the locomotive runner to see the signals. Electric locomotives would have required trolley wires or a third rail, either of which would have introduced serious difficulties in many locations too obvious to require explanation. Storage battery electric locomotives might have been used, but they are not adapted to severe and continuous service, and require too long a time for recharging the batteries or changing the cells.

When the reduction works were built, the engineers in charge decided in favour of compressed air locomotives as the best solution of the trans-



THE TRAIN CARRYING CALCINES RUNS BETWEEN THE ROASTER PLANT AND THE REVERBERATORY FURNACES
COLOURED MEN OPERATE THIS LOCOMOTIVE BECAUSE THEIR SKIN STANDS THE GASES AND HEAT
BETTER THAN THE WHITE MAN'S

portation problem. Their successors who now operate the plant apparently agree with them, as they have purchased additional compressed air locomotives, and have extended the system to cover movements of materials which the constructing engineers did not consider in connection with the original design. The writer heard but little criticism and much commendation. The general opinion of the operating force is thus summarized:—Under their conditions, compressed air locomotives are unsurpassed for convenience, reliability, and simplicity of operation.

Taking up the question of economy, the labour cost of operating the system is as low or lower than it would be with any other system. With them the cost of power is also extremely low, as the steam is generated by waste heat from the reverberatory furnaces; but as the question of steam economy is of considerable interest under other conditions, and as an absolute determination was impossible under the circumstances, the writer will attempt a few comparisons, trusting that they may be found of interest.

During the month of April, the two compressors were operated continuously twenty-four hours a day, one at an average speed of 38.8 revolutions per minute; the other at 44.1 revolutions per minute. Under these conditions the total power developed would be 721 H. P. for both compressors, or an average of about 66 H. P. for each locomotive in operation. Ten out of the eleven locomotives in operation will develop 5700 pounds tractive force; the remaining locomotive will develop 9180 pounds. The speed is limited to 5 miles per hour.

Each one of the smaller locomotives would therefore be developing

$$\frac{5700 \times 5280 \times 5}{60 \times 33000} = 76$$

horse-power at times; the large one

$$\frac{9180 \times 5280 \times 5}{60 \times 33000} = 122$$

horse-power, giving a total of $76 \times 10 = 760$, added to $122 = 882$ horse-power.

The approximate kilowatt input of an electric locomotive of the same weight as the smaller type of compressed air locomotive would be 95, and for the larger size 150; total, $95 \times$

10 = 950; 150 × 1 = 150; 950 + 150 = 1100 kilowatts.

If we assume that not more than one-half of the total rated capacity of the locomotives will be called for at any one time, we have 550 kilowatts, or 550 × 1.34 = 737 electrical horse-power at the locomotives, to which must be added 5 per cent. for line losses, 5 per cent. for dynamo losses, and about 7 per cent. for the friction of the engine; 737 × 1.17 = 862 for the indicated horse-power of the engine driving the dynamo to operate the same number and weight of electric locomotives, with occasional overloads and the extreme fluctuations incident to the operation of electric locomotives. It does not seem, therefore, as though electric locomotives under the same conditions would be much more economical of steam.

As compared with steam locomotives, in order to make an intelligent comparison we must go back to the coal pile, even though the steam necessary to operate the compressed air locomotives at the reduction works is obtained from boilers that are run by waste heat.

The two compressors, under normal conditions, required 323,100 pounds of steam per day of twenty-four hours. By referring to the table on page 471 we see that there are thirty-one eight-hour locomotive shifts in each day of twenty-four hours. Assuming, for the sake of comparison, an evaporation of 7½ pounds of water per pound of coal, we find that to furnish steam for the compressors, 43,080 pounds of fair coal would be required, or, say, 1400 pounds of coal per compressed air locomotive shift. The writer has in his possession reports on the performance of twelve steam locomotives, having cylinders 9 inches in diameter by 14 inches stroke, which used from 760 to 2400 pounds of coal per day of ten hours, averaging about 1340 pounds.

Assuming that steam locomotives at the reduction works would use approximately the same quantity of fuel per hour, we have 1072 pounds for the small locomotives per shift, and 1500 pounds for the large one, giving a total of 1072 × 29 = 31,088, 1500 × 2 = 3000, 31,088 + 3000 = 34,088, or, say, 17 tons of coal for the steam locomotives doing the same work, as against 21½ tons for the compressed air locomotives.

A "TRAMP" LOCOMOTIVE AND CARS FOR MISCELLANEOUS WORK

These calculations are, of course, nothing more than crude approxima-

FINE CONCENTRATES TRAIN. THE LOCOMOTIVE HAS A ROOF OF SHEET METAL TO PROTECT IT AS MUCH AS POSSIBLE AGAINST THE DRIPPING BINS FROM WHICH THE CONCENTRATES ARE DRAWN

tions, and are presented only as indicating that any change which might be effected in the cost of steam to operate the transportation system by substituting another form of motive power would be of minor importance when considered in connection with other expenses and the other desirable qualities of the existing system.

The cost of maintenance must certainly be less than with steam locomotives by about the amount necessary to wash out and keep in repair thirteen small locomotive boilers, as the cost of keeping the main storage tanks on the compressed air locomotives in repair has been nothing. The re-remainder of the machinery of the compressed air locomotives being so nearly the same as that of the steam locomotive, there is no reason why there should be any difference in the cost of maintenance. The writer is of the opinion that the repairing of saddle tanks and the renewing of grate bars on steam locomotives would about balance any expenditure for maintenance of a stationary plant, including the boilers.

In comparing the cost of maintenance with electric locomotives no such direct deductions are possible. The machinery is radically different, and the friends of both systems claim superiority in this respect for their favourites. With the electric locomotives, dust and dirt are more easily kept away from the wearing parts; but the same casing that keeps out the dust prevents the free circulation of air around the armature and commutator, and renders them more liable to injury from overheating. So little reliable data is to be had that it is all a matter of opinion. Figures have been published showing that compressed air locomotives are more economical to maintain than are electric locomotives, but there are no detailed and reliable figures to show electric locomotives more economical than compressed air locomotives.

One set of figures, however, does not settle the matter. Probably local conditions and designs have more to do with the relative cost of maintenance than any inherent qualities of the two systems. Compressed air locomotives have this advantage: charge after charge of air may be used in quick succession, with the locomotive working at all times at full capacity without injury. This is not true of electric locomotives. The electric motors which drive the locomotives are so designed that they can be run for one hour at rated draw-bar pull

and speed without injurious heating, provided the motors are started cold. As a rule, this provision is sufficient, but occasionally it is not, and a burnout occurs.

The problem of internal transportation in many large establishments is a serious one, and during the writer's stay at Anaconda the many advantages of compressed air locomotives for such service were so manifest, and the evidence that their development had reached a stage justifying the confidence of engineers and business men was so conclusive, that a brief account of what was being accomplished with this form of motive power seemed of general interest.

Compressed air locomotives, however, have their limitations. They are not intended for long continuous runs in one direction, and their efficiency would be relatively low where starts and stops were infrequent; but for service conditions similar to those existing at the Anaconda Copper Mining Company's new reduction works there would seem to be a wide field of usefulness, more especially where waste heat from heating or blast furnaces, or the refuse from woodworking establishments, or water power, could be utilized to operate the compressor, thus saving the fuel necessary to operate steam loccomotives, doing away with trolley wires, and eliminating all risk of fire.

CONTINENTAL MACHINE TOOLS AT THE LIEGE EXHIBITION

By Joseph Horner

A STATUARY GROUP AT THE LIEGE EXHIBITION

THOSE who saw the Paris Exhibition of 1900 might be somewhat disappointed at the show of machinery at Liége, for, although it has much of interest, we think of the many big firms in France and Germany who are not there, but who were in evidence at Paris. Yet Liége is a large city, and the site chosen for the Exposition is an ideal one, flanking both banks of the broad Meuse and having as a background the stately slopes of the hilly parts of the suburbs. It is the center, too, of vast industries. Seraing, with the Cockerill works and its 10,000 hands, is only eight miles away, and the tram line that connects the two, running nearly parallel with the Meuse, passes by hosts of factories, big and little. The east end of Belgium is a veritable hive of industry, in which women take their share with the men.

In the Exhibition grounds, served by a light railway, there are many attractions, ranging from the local women's industries, as lace making

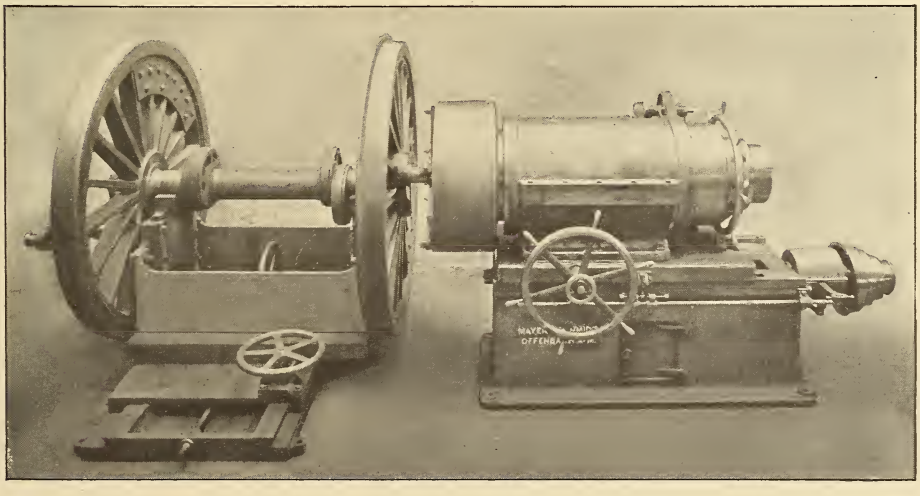


FIG. 1.—A GRINDING MACHINE FOR TRUING CRANK PINS. MADE BY MESSRS. MAYER & SCHMIDT, OFFENBACH-ON-THE-MAIN, GERMANY

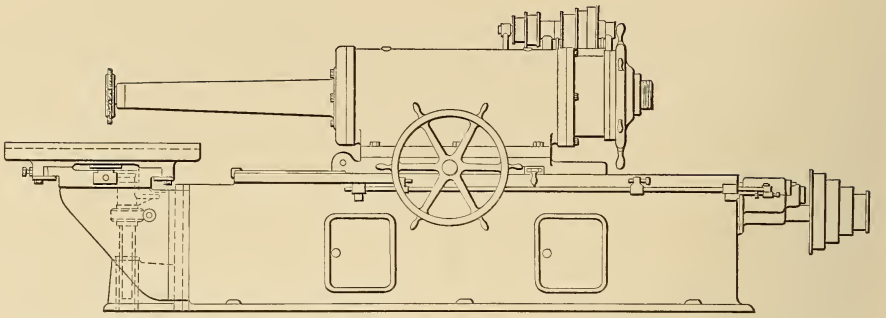


FIG. 2.—A CYLINDER-BORE GRINDING MACHINE SHOWN BY MESSRS. MAYER & SCHMIDT

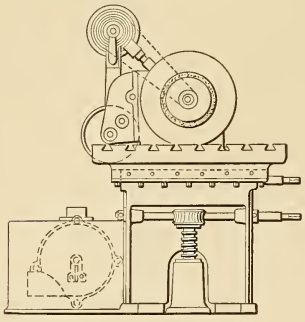


FIG. 3.—AN END VIEW

and much else, to the truly magnificent display of Canadian products, which are housed in a large building by themselves. The machine tool exhibit is in one area roofed in along with locomotives and metallurgical exhibits. American firms, such as the Brown & Sharpe Manufacturing Company, of Providence, Rhode Island, are well represented by their agents, Fenwick, Frères & Co., and Schutte.

At the Brown & Sharpe stand, the author was much interested in the Beale generating bevel-gear cutter, and in a new motor-cylinder grinder which the firm has recently brought out. The most interesting British exhibits are a Herbert turret lathe and two Armstrong-Whitworth high-speed lathes. Continental firms, of course, predominate, but there are few novelties, and apparently some of the exhibiting firms do not seem to think it worth their while to have attendants at the stands. At several the author saw no representative; at others, workmen only. Moreover, the buildings close at 6 p. m., so that evenings must be lost, or occupied in the grounds.

This article will deal only with the Continental tools, because, although British and American machines are shown, they are more familiar to our readers. The Continental firms have not made a very striking exhibit, though a few have done very well. The machine tool exhibits are rather dwarfed, too, beside other attractions adjacent in the same building, such as locomotives and carriages, big gas engines, electric generators, trophies of steel, copper, and brass, models of big mines and works, etc.

The stand of Messrs. Mayer & Schmidt, of Offenbach-on-the-Main, is very fully equipped with grinding machines of various types, a few only of which can be noted. The development of the automobile has been responsible for much activity among machine tool builders. At Liége there are three machines for grinding the cylinders,—one by the Brown & Sharpe Manufacturing Company, another by Friedrich Schmaltz, and a third by Mayer & Schmidt, which is shown in Figs. 2 and 3. The last-named is not the first made by this firm, but it is the largest, being capable of grinding bores up to about 12 inches in diameter and about 40 inches in length.

The example shown in Figs. 2 and 3 is a horizontal type, which

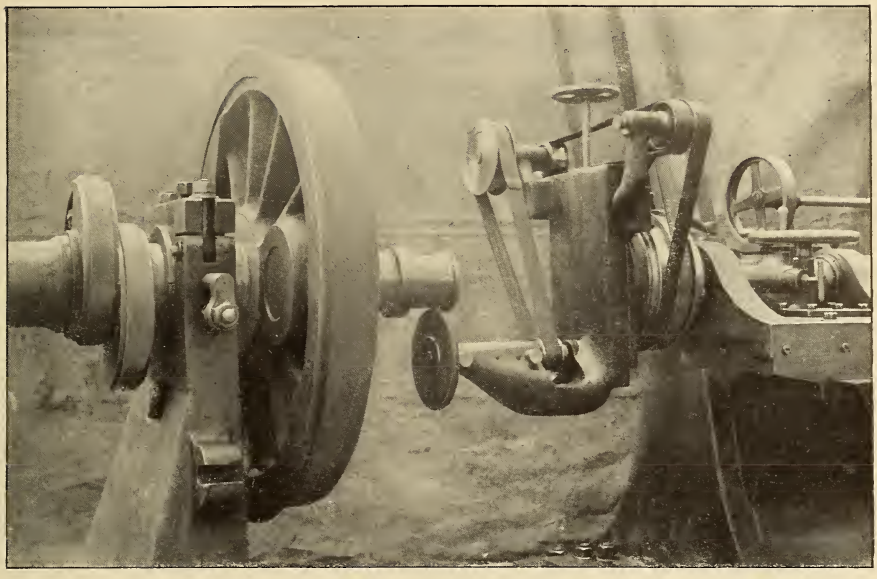


FIG. 4.—A MACHINE MADE BY MESSRS. MAYER & SCHMIDT, FOR TRUING CRANK PINS ON AXLES. THE GRINDING WHEEL REVOLVES AROUND THE PIN, AS WELL AS WITH ITS OWN SPINDLE

appears to be the stiffest design. The cylinder is carried on a tee-grooved table on a horizontal bed, which receives the grinding head at one end. The wheel is, of course, considerably smaller than the hole which it grinds, because a bore could not be finished truly with a wheel of the same size, owing to wear. It, therefore, has, in addition to its rotary movement, an eccentric one, which is capable of regulation as the grinding proceeds, and is also adjustable automatically. When a given size of hole is ground, an automatic throw-out comes into operation. The mechanism enclosed in the head runs in an oil bath, and there is a dust-removing device.

A machine which is useful for locomotive shops is the vertical link grinder of this firm. It

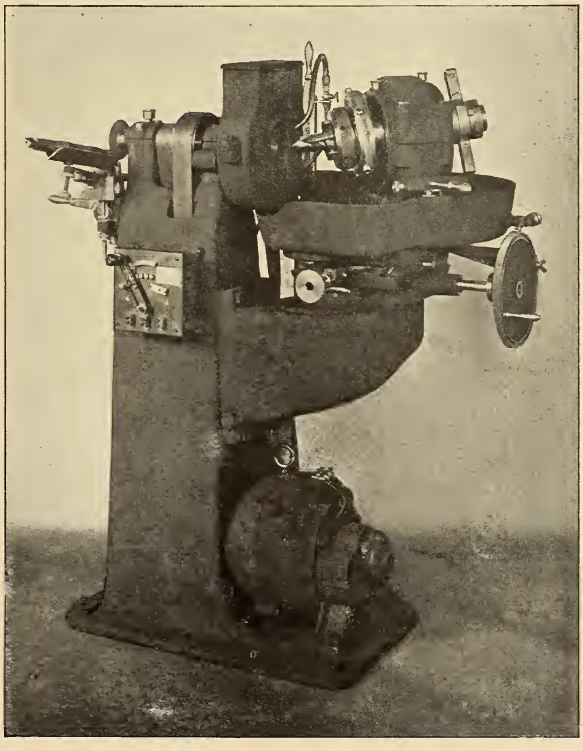


FIG. 5.—AN AUTOMATIC TWIST-DRILL GRINDER MADE BY FRIEDRICH SCHMALTZ, OFFENBACH-ON-THE-MAIN

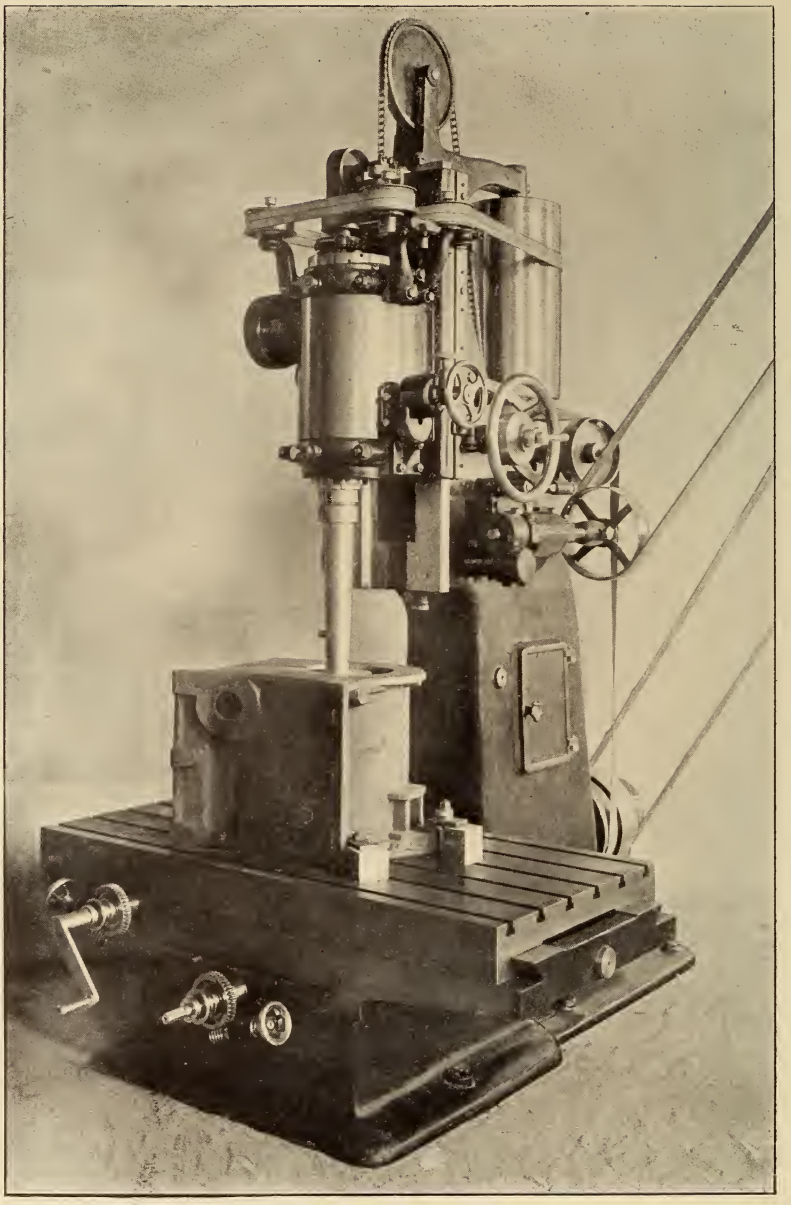


FIG 6.—A VERTICAL CYLINDER-BORE GRINDING MACHINE, WITH ECCENTRIC SPINDLE. BUILT BY FRIEDRICH SCHMALTZ, OFFENBACH-ON-THE-MAIN

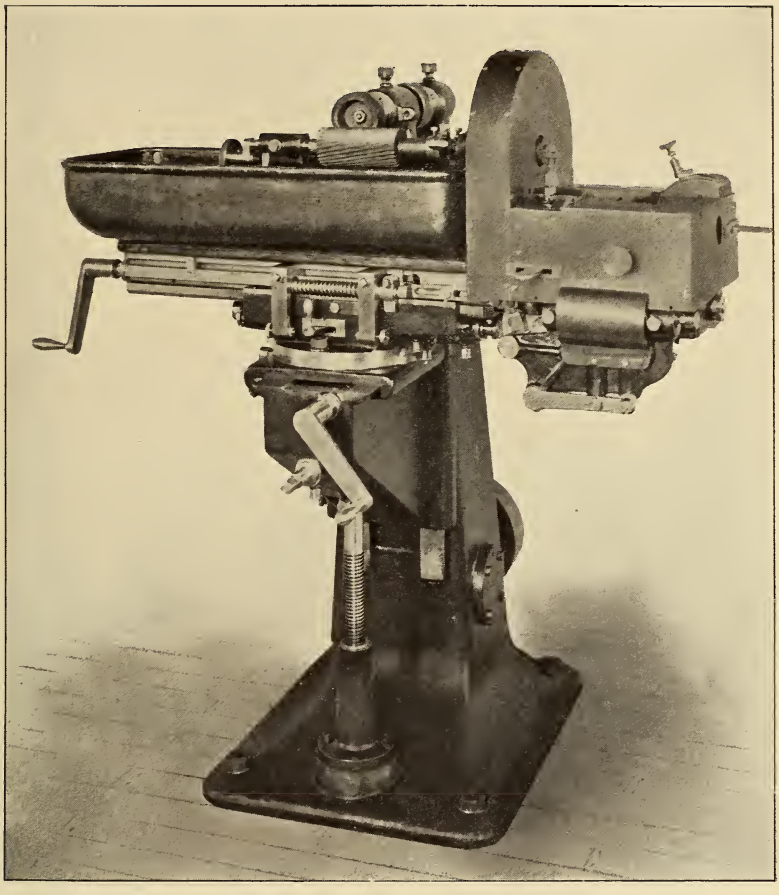


FIG. 7.—A CUTTER GRINDER OF THE PILLAR-AND-KNEE TYPE. BUILT BY FRIEDRICH SCHMALTZ

comprises a framing with front slide and table, against which a vertical radius arm is attached, carrying the link to be ground on its upper end. The eccentric grinding mechanism is the same as those in the cylinder grinders and bush grinders of this firm, namely, the cylinder that encloses the grinding spindle has its axis set diagonally in relation to the outer or main cylinder carried in the head and its periphery parallel with the axis of the grinding spindle.

The diagonal fitting permits of eccentric movement and adjustment. The main sleeve is rotated slowly through gears with the eccentric spindle, while the one for grinding is revolved at a high speed. The radius for different links is obtained by a screwed rod operated by bevel gears. The link is moved to and fro by belt pulley and reversing bevel gears, operating a screw.

The eccentric grinding fitting is rigged up for various purposes. At the exhibition, one is shown truing crank pins in place on the wheels and axles. This is shown in Fig. 4. The wheels and axles are carried in bearings adjustable vertically on a base plate, by which the axles are adjusted for centres and presented to the grinding wheels. The grinding wheels are carried in a head to which the longitudinal traverse feed is imparted. There are two wheels which can be used on directly opposite sides

of the pin, or one in advance of the other, so that two separate portions can be ground simultaneously.

A cam-grinding machine for the cams of gas engines is an illustration of the omnivorous character of the grinding processes of the present day. The cams to be ground are mounted on a mandrel, which also carries a former of the same shape as the cam to be ground. A roller is pressed by a spiral spring against the former, and this is connected by a lever to the support on which the grinding wheel is carried. The lateral feed is performed automatically.

Besides these, and pin grinders, Messrs. Mayer & Schmidt have planer grinders of pillar-and-knee and long-table types. In both, the wheels are traversed by lever mechanism as they revolve. The value of these machines lies in work which has hitherto been appropriated by shaper and planer. Such work as motion bars, valve faces, link faces, the flats of connecting rod ends are cases in point. The various movements are automatic. These machines have their wheels protected with corrugated sheet guards.

Messrs. Mayer & Schmidt have a new twist-drill grinder, one of that very small class in which the drill rotates continuously, the grinding taking place on each lip in succession instead of one lip being finished before the other is commenced. The angle is obtained by the adjustment of the slide rest, and both the clearance and the cutting angle can be altered by the workman while the machine is running.

Machines for sharpening band and circular saws, as well as the saws themselves, are much in evidence. The displacement of hand filing in all shops of any size can only be a question of time. It is rather surprising to see how numerous these designs are, not only as modified by the positions of the saws, which are horizontal in some cases and vertical in others, but by the methods of pitching and grinding adopted, both being capable also of regulation. Pitching can be altered, as can also the angle of sharpening, that is, the diagonal position of the wheel corresponding to the oblique location of the file for rendering the teeth more or less incisive.

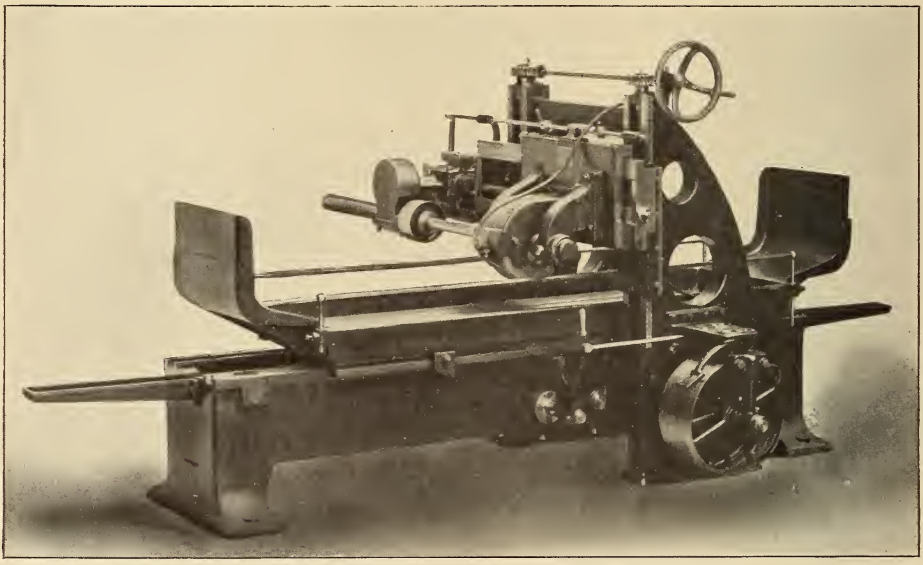


FIG. 8.—A PLANER-TYPE GRINDING MACHINE FOR SURFACING LARGE PIECES. BUILT BY FRIEDRICH SCHMALTZ

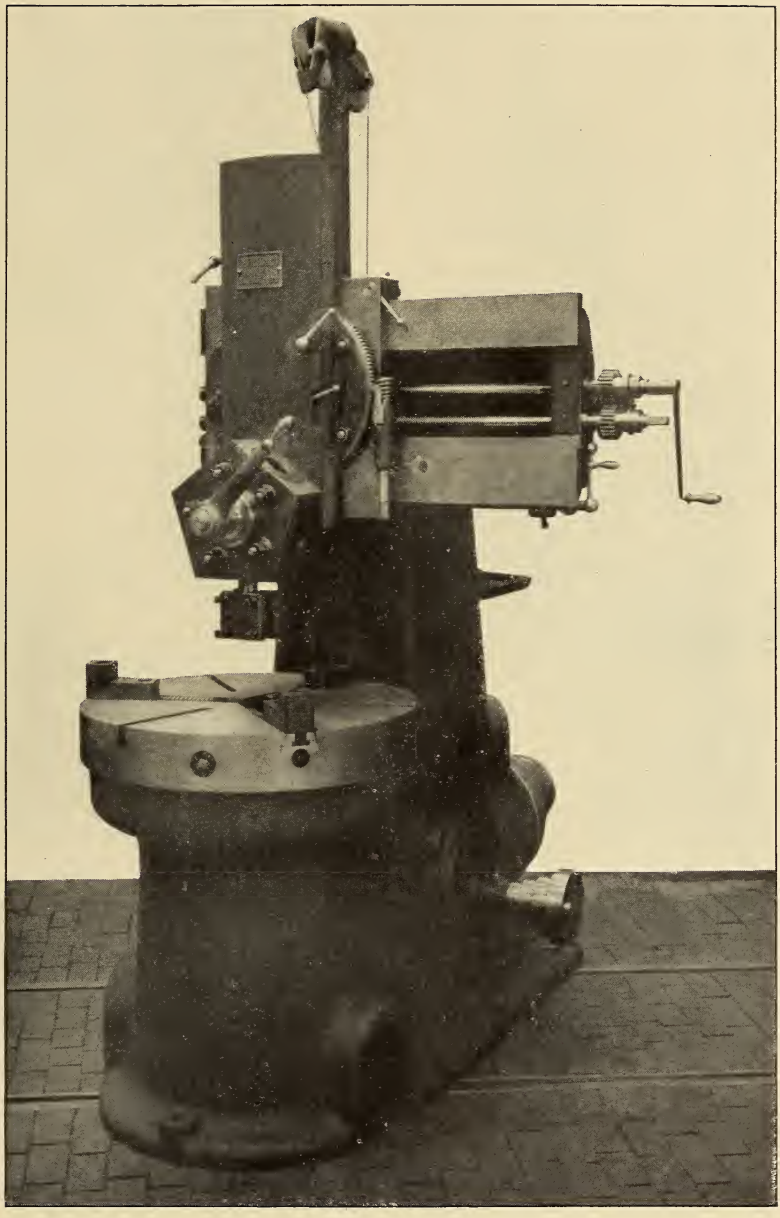


FIG 9.—A VERTICAL BORING MACHINE WITH TURRET FOR FIVE TOOLS. BUILT BY MESSRS. DE FRIES & CO., LTD., DUSSELDORF, GERMANY

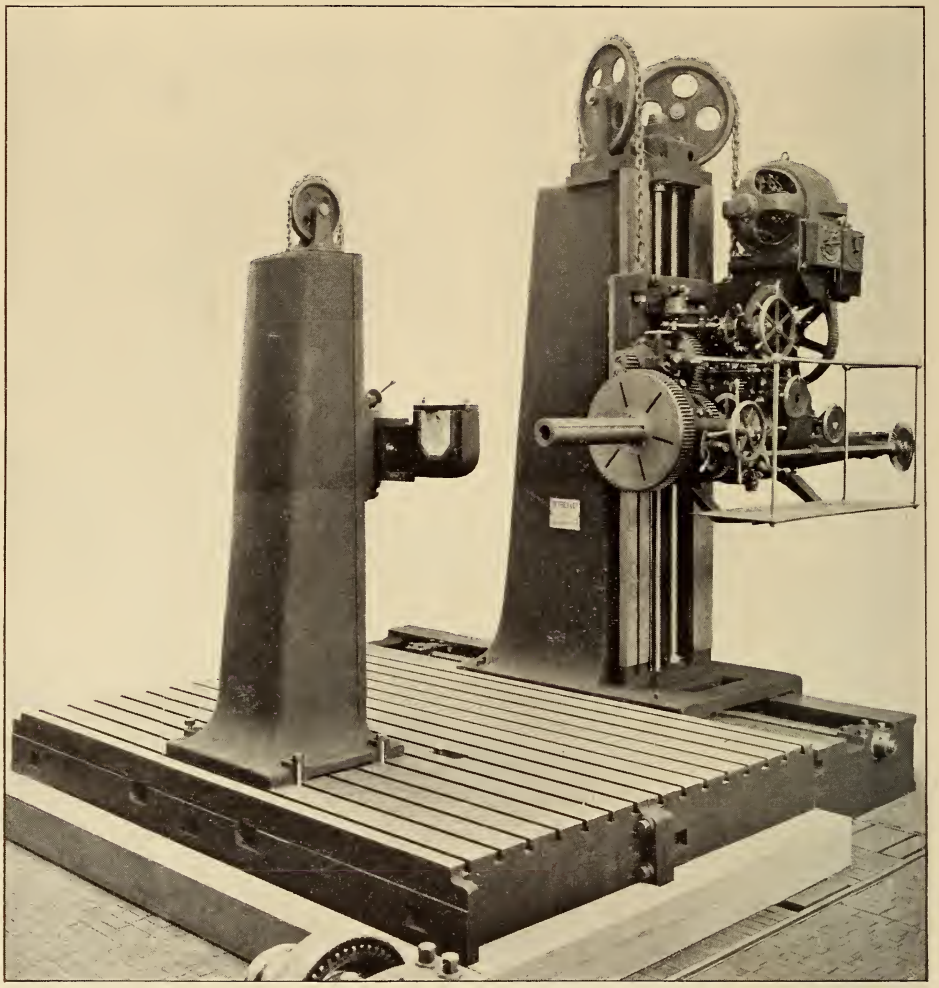


FIG. 10.—A HORIZONTAL BORING, DRILLING, TAPPING, AND MILLING MACHINE, ELECTRICALLY DRIVEN. BUILT BY MESSRS. DE FRIES & CO., LTD., DUSSELDORF

In the Mayer & Schmidt machines there is a dust-exhausting device which draws the dust to the interior of the machine frame. This contains a quantity of coke upon which the dust is caught. MM. Panhard & Levassor also have saw-sharpening machines, both band and circular.

Friedrich Schmaltz, of Offenbach-on-the-Main, shows a twist-drill grinder, illustrated in Fig. 5, the feature of which is that the drill rotates continuously during grinding. The mechanism, which is all concealed, is ingenious, and the effect is to produce a combined rotational movement in a conical path and traverse movement. The automatic throw-out, the relocking at the termination of the grinding of one lip, and the commencement of that of the other, go on until both lips are completed. A number of collets are provided for gripping drills of varying sizes.

The firm also show a large number of other specialities in grinding machines. A vertical cylinder-bore grinding machine, shown in Fig. 6, is of interest. The two movements of the wheel, rotary and eccentric,

are provided for by a spindle and bush, set with axes parallel, but eccentrically placed. The diameter can be adjusted during revolution, and depth for grinding also, so that the height of table remains constant. The weight of the head and grinding apparatus is counterbalanced by a weight suspended from a pitch chain passing over a pulley. Tension pulleys maintain the belt taut, and the long drum allows the belt to move vertically in unison with the motion of the grinding head. The length of the table is sufficient to permit of two cylinders being operated on, so that the attendant might be fixing one while the other is being ground.

In favour of the vertical design over the horizontal, there is the greater ease of fixing the work and the falling away of the dust, as well as the more problematical question of sagging of the spindle and its bearing, which may be considered as possible in a horizontal machine.

There is also a cutter grinder of rather novel design at this stand, in which the heads, the arbour, and work are entirely surrounded by a deep trough coming up from the sides of the table. The machine, as shown in Fig. 7, is of the pillar-and-knee type. The table swivels around a graduated base for angular work, and dogs render the reversals automatic.

A Schmaltz planer-type grinder with long table, illustrated in Fig. 8, is noticeable on account of the prominent guards fitted at the sides and ends of the table to catch the dust. The grinding wheel is carried on a cross slide, and is driven by a splined shaft which slides with the side traverse through the bore of the driving pulley. In other respects the machine greatly resembles an ordinary planer.

The vertical boring mill in Fig. 9, made by the De Fries & Cie. Actien Gesellschaft, of Düsseldorf, is shown with a motor placed between the housings, whence a short drive takes place through a link belt. The machine has two tool rams with all movements. A smaller single ram machine carries a turret for five tools, and a table with three jaws.

A horizontal boring, drilling, tapping, and milling machine of the floor type, also at this stand, is driven

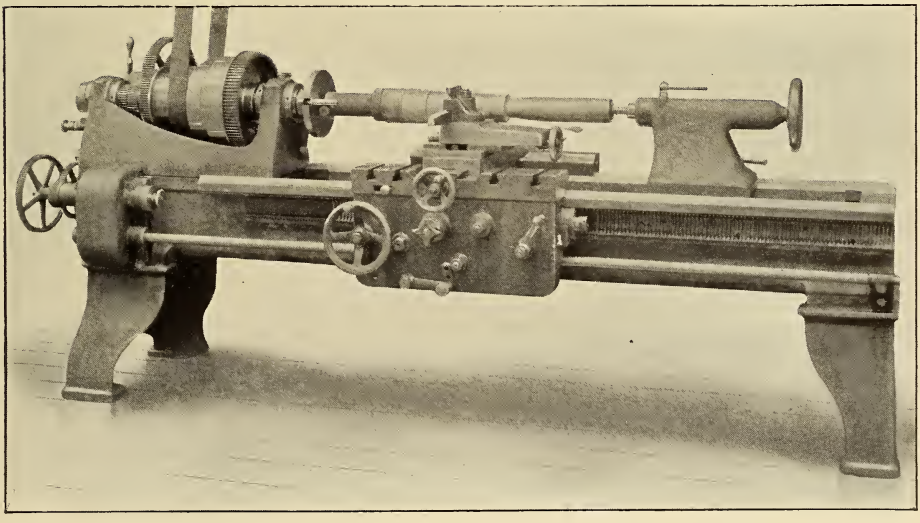


FIG. 11.—A SCREW-CUTTING LATHE MADE BY MESSRS. DE FRIES & CO., LTD. THIS LATHE HAS A SEGMENTAL NUT ATTACHED TO THE FRONT FACE OF THE BED INSTEAD OF THE USUAL LEAD SCREW

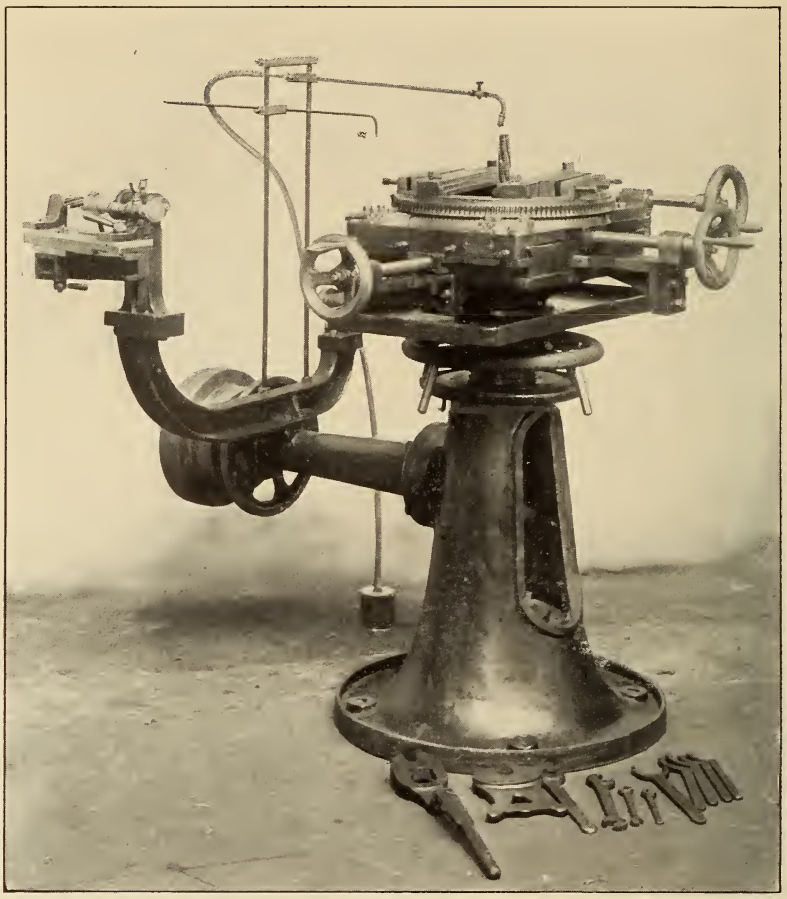


FIG. 12.—A DIE-CUTTING AND MILLING MACHINE WITH CUTTER PROJECTING FROM BELOW. MADE BY CURD NUBE, OFFENBACH-ON-THE-MAIN

electrically by a motor mounted on the vertically sliding head, a platform for the attendant being there provided. The outer standard is bolted down to a slotted table, as shown in Fig. 10, and carries the end of the bar when necessary. The driving head standard can be traveled along slides at the end of the slotted table.

A novelty of considerable interest at the same stand is a special screw-cutting lathe, shown in Fig. 11, which, instead of the usual lead screw, has a segmental nut attached to the front face of the bed; this provides the means of traveling the rest for cutting screws. The chief advantages claimed are that distortion or extension of the screw is rendered impossible, chips cannot reach the threads, the pull is nearly directly under the cut, and the nut may be easily renewed. The handles for controlling the sliding, surfacing, screw cutting, and reversing motions are located in the apron for convenience of operation.

Another special type of lathe shown is one for turning bevel gear blanks. The swivel slide rest is fitted with a graduated base, and power feed to the top slide is put into operation at any angle, so that the rest need not be worked by hand. The graduations enable the rest to be set exactly, without the necessity for using tests.

Among other machines may be noted a tool-room grinder for turning and planing tools, modeled after the Gisholt type, the tools being held in a swiveling carrier, so that presentation may be effected at any angle to the grinding wheel.

Curd Nube, of Offenbach-on-the-Main, has a very complete exhibit of his special milling machines. The cardinal feature of these is that the spindle comes up from below through the table, as shown in Fig. 12, so that the cuttings fall down from the tool. But around this feature several designs and details have been evolved with the object of increasing the utility of the machines. The machines are specially designed for the manufacture of dies and their tools, and all that pertains to them, including drilling and grinding. As the spindle does not move vertically, adjustments are effected at the table,—

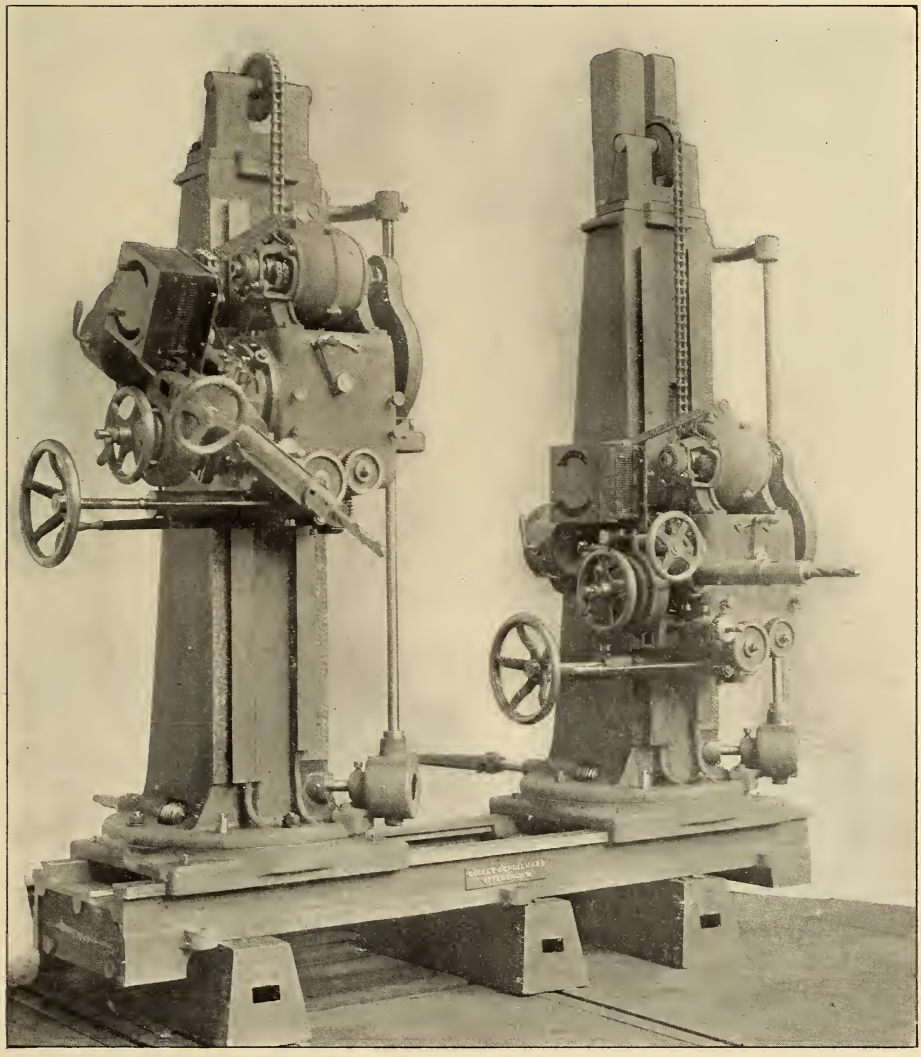


FIG. 13.—A PORTABLE ELECTRICALLY-DRIVEN DRILLING MACHINE FOR BOILER WORK. BUILT BY MESSRS. COLLET & ENGELHARD, OFFENBACH-ON-THE-MAIN, GERMANY

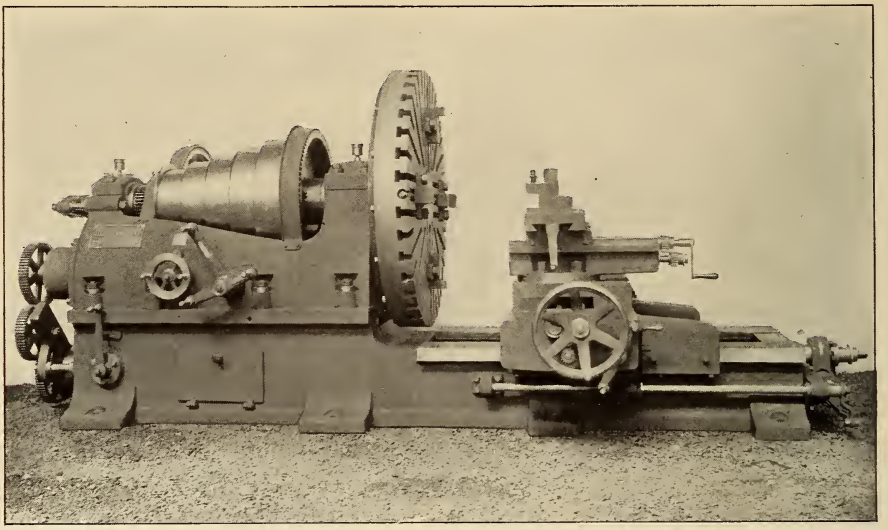


FIG. 14.—FACE LATHE WITH NEST GEARS FOR SCREW CUTTING. MADE BY THE ATELIERS DEMOOR, BRUSSELS, BELGIUM

vertically, circularly, and laterally, as well as for form outlines. The methods of movement vary in the different types.

The table is of compound type, and in the illustration it is adjusted vertically in the pillar, which is prolonged into a cylindrical boss encircled by a sleeve coming down from the stand on which the table slides are carried. The lower portion of the pillar base is threaded to receive the hand-wheel, from the rim of which handles are seen coming down in diagonal directions, and thus the table receives its vertical adjustments. Its lateral movements are produced by the slides seen, and its rotary movements by the worm gear turning the V-edged plate below it. Work is held in the jaws seen on top, which are provided with clamping screws, besides which a T-grooved table is fitted.

Circles or circle arcs in holes or on outer edges are done by the rota-

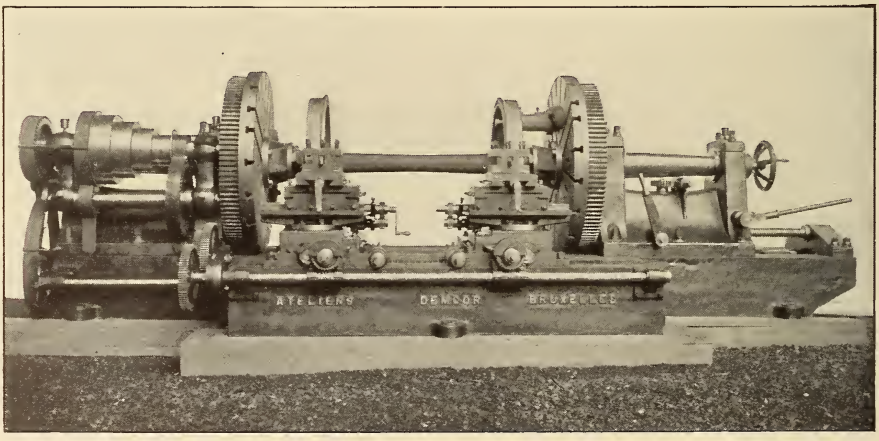


FIG. 15.—A DOUBLE-WHEEL LATHE BUILT BY THE ATELIERS DEMOOR

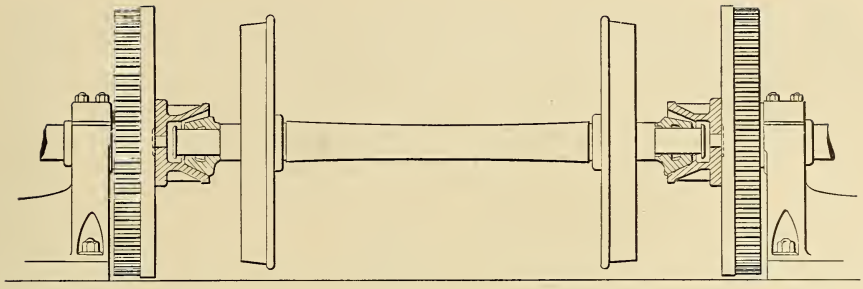


FIG. 16.—JOURNAL CLINCHING DEVICE MADE BY THE ATELIERS DEMOOR

tion of the table, while linear edges are accomplished by the traverse slides, and any outlines by a combination of these movements. A pump is fitted, and, though not shown here, many have self-acting power movements through a telescopic shaft to the rotary table. The spindle is driven from the stepped cones through miter gears.

The utilities of this fundamental type are increased, first by the addition of an upper spindle, and further by that of a horizontal one. The upper spindle may be used as a facing tool employing an end mill, thus taking the place of the planer and shaper. Or it may be used as a steady rest for the lower spindle by fitting a counterpoint. The upper spindle is used as a stamp cutter and the lower as a die cutter. The upper spindle has vertical adjustment. In several of the types, its bearings are made to angle on the face of the machine framing, so permitting of angular milling. Lastly, it may be run in unison or independently of the lower

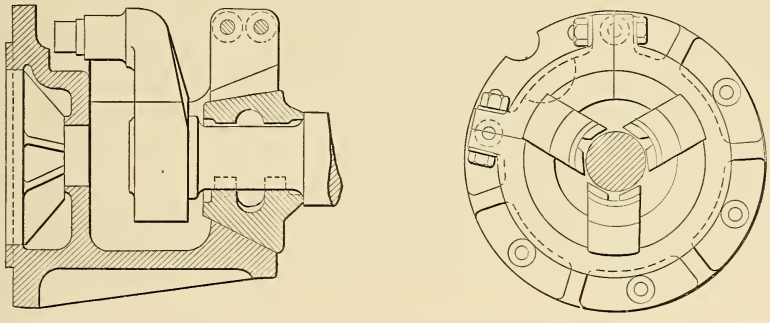


FIG. 17.—A CHUCK FOR AXLES WITH CRANK PINS, AS USED BY THE ATELIERS DEMOOR

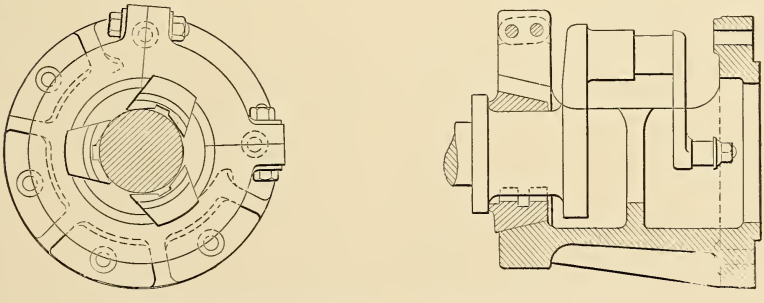


FIG. 18.—ANOTHER CHUCK FOR AXLES WITH CRANK PINS

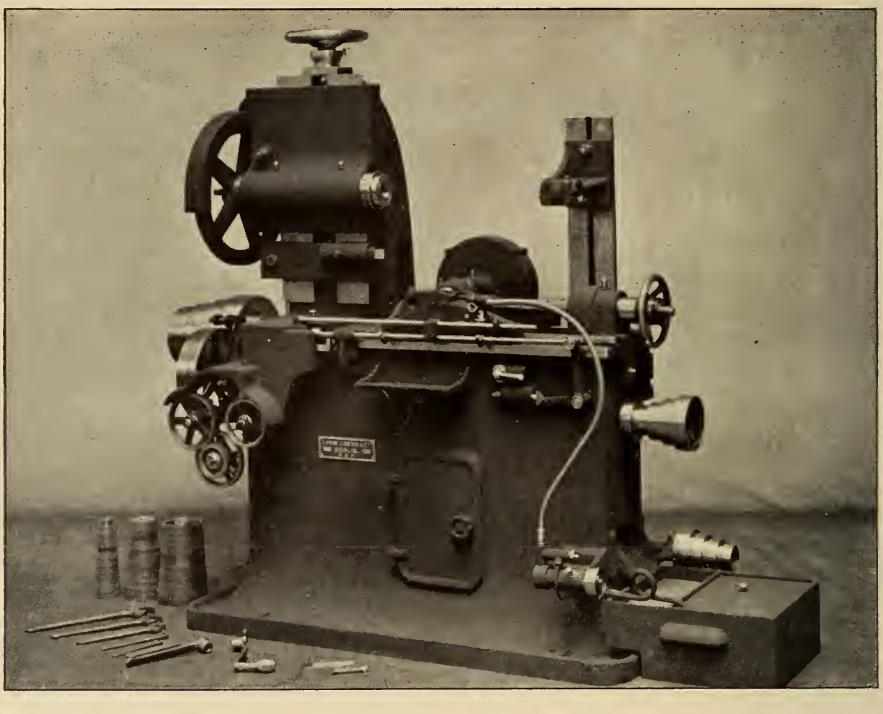


FIG. 19.—A SPUR-GEAR CUTTING MACHINE MADE BY MESSRS. LUDWIG LOEWE & CO., INC., BERLIN

one. The inclusion of a horizontal spindle in the most complete machines permits of doing horizontal milling on a circular compound table. An overhanging arm is provided, coming out from the lower bearing of the vertical spindle, to give suitable support to the horizontal spindle. In some examples a high-speed belt drive is adopted; in others, gears only are used.

In the two and three-spindle machines, the table is carried differently from that described on the stand machines, being supported on a knee sliding on the vertical face of the framing, and on a circular boss surrounding the spindle. It is elevated by worm gear actuating a stiff vertical screw which works in a nut let into the main framing of the machine. In some of the types an oval chuck is fitted for milling out dies of that form. These, and numerous samples of work, are shown at the firm's stand.

Messrs. Collet & Engelhard, of Offenbach-on-the-Main, have a good show of special machines, most of which are out of the common, being of the portable types, for drilling, tapping and shaping. See Fig. 13. Some radiator machines are also rather unusual, comprising boring and facing spindles, and in some cases threading spindles for operating on both ends of radiator elements.

The Ateliers Demoor, of Brussels, show examples of their various heavy lathes, face, wheel, and vertical. The No. 1 face lathe is noticeable for the breadth of the steps on the cone. It has three steps, and is treble back-geared. The rests have three self-acting movements, with four rates of travel obtained by gears which permit of changing while in motion. The No. 2 face lathe, shown in Fig. 14, has a five-stepped cone. As in the other lathe, the rest has four changes of speed. A changing mechanism in connection with the lead-screw drive gives seven variations and this, with the four in the

rest, allow of twenty-eight in all, obtainable instantly.

A double-wheel lathe, also shown by Ateliers Demoor, is a fine tool, using high-speed steel and weighing about 40,000 pounds. Perhaps the most interesting feature of this tool, illustrated in Fig. 15, is the chucking arrangement, shown in detail in Fig. 16. This device is an alternative to the practice of employing centers in the axle ends. A casting, coned inside, carries three jaws which by be-

cranks, such as are found on so many Continental locomotives. This chuck has a clearance chamber to accommodate the crank. Two examples are shown in Figs. 17 and 18.

Ludw. Loewe & Co., Inc., of Berlin, have a good exhibit, including the following:—

An automatic spur-gear cutter shown in Fig. 19, in which the work mandrel is carried between a fixed head and a steady; it is adjustable along one face of the bed, the cutter

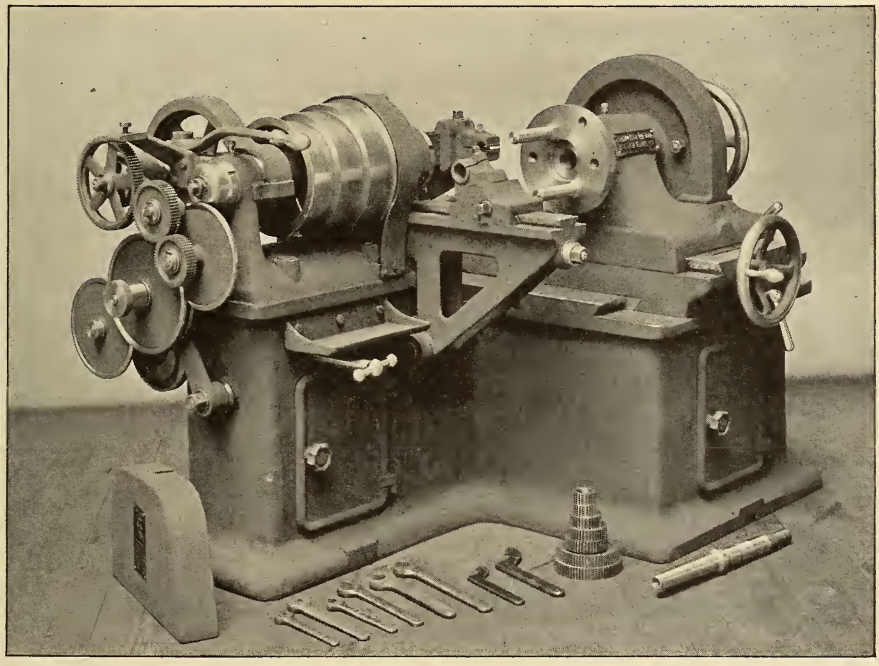


FIG. 20.—A CIRCULAR MILLING MACHINE MADE BY MESSRS. LUDWIG LOEWE & CO., INC.

ing pushed inwards are caused to grip the journal concentrically. In this way the concentricity of the wheels with the journals is insured, a feature especially useful for truing up worn wheels, since the old turning centers in the axle ends may not afford a true guide for running. By gripping the actual journal, no inaccuracy can be possible.

The driving is effected by pins carried out from the face plates to the wheel arms. A modified form of chuck is employed for axles with

being traversed on this bed under the blank. The pitching is by change gears, worm, and large worm-wheel, and the reversals are effected through dogs. A flexible tube conveys the lubricant to the cutter from a centrifugal pump which draws its supply from a tank at one end of the bed. The Warren automatic bevel-gear cutter is also shown, being a type which mills theoretically correct teeth without the use of a former or templet.

In addition, there is a circular

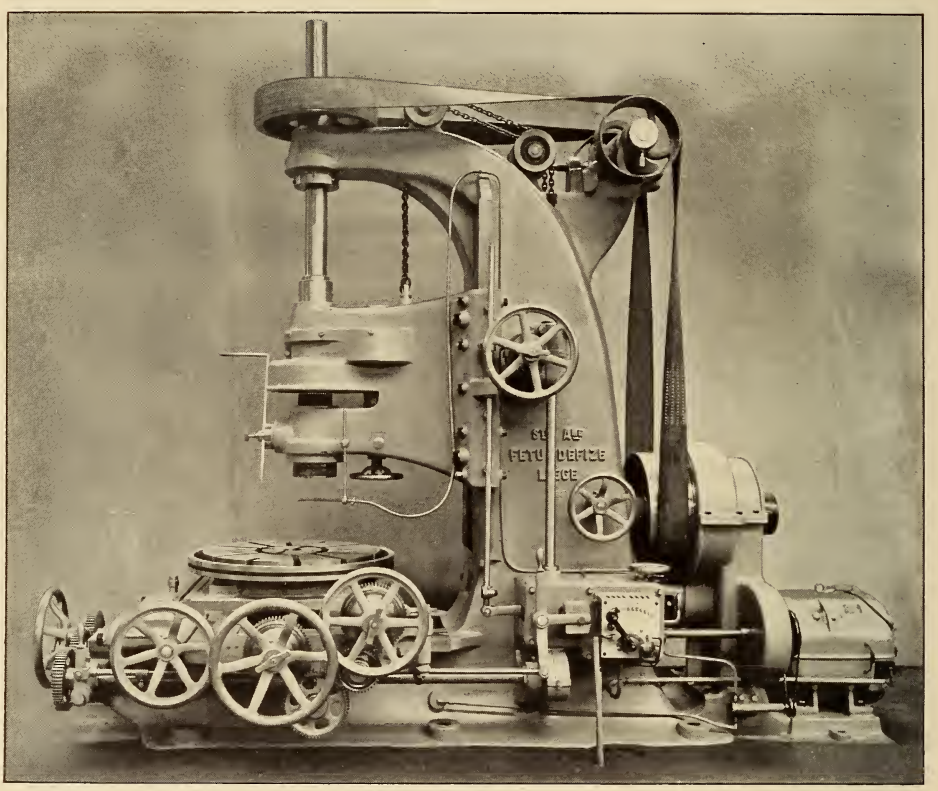


FIG 21.—A VERTICAL MILLING MACHINE OF THE SLOTTER TYPE, BUILT BY THE SOCIETE ANONYME DES ETABLISSEMENTS FETU-DEFIZE, LIEGE. THE MACHINE IS DRIVEN BY A 6-H. P. MOTOR

milling machine, shown in Fig. 20, which gives an indication of how lathe work is being invaded by milling processes. This machine mills around the rims and faces of all classes of discs, wheels, pulleys, etc., employing a form cutter of suitable profile with a considerable saving over ordinary turning. If both rim and faces have to be treated, the cutter may be made up in three parts, interlocked, which is more convenient for manufacture and for sharpening. The firm have also two Norton grinders on show, a heavy plain machine, and a universal tool and cutter grinder.

L. Soumagne & Fils, of Liége, have something of a novelty in the shape of a small slotting machine fitted with a four-tool turret to the ram, so that intricate work may be accomplished rapidly. The travel of the ram is 4 inches. They have a form or profile milling machine in which the spindle is spring balanced.

The Société Anonyme des Établissements Fetu-Defize, of Liége, have a vertical milling machine of the slotter type, shown in Fig. 21, in which the spindle is carried on the face of a tall framing, and the tables on the base. A round table on the top allows of circular milling. A 6-H. P. motor drives the machine.

Two other machines are:—a vertical turning mill, taking up to $6\frac{1}{2}$ feet in diameter. An interesting feature about this is that the firm have discarded the friction disc and roller used in former machines, employing instead a nest of gears, on the Hendey-Norton principle, for feeding the tools at varying rates. A horizontal

boring, drilling, and milling machine of the floor type has the driving head carried on a traveling column.

The helical gears are a strong feature in this exhibition, being very popular on the Continent. At the stand of Citroen, Hinstin & Cie., some curious types are seen in which the number of diagonal herring-bonings are increased from two to three or four, duplicating therefore the ordinary gears. Fig. 22 shows a wheel and pinion of triple-form teeth. These are applied to spurs, and to bevels, and are cut. Such gears can be depended on only when they are perfectly hung and cut accurately.

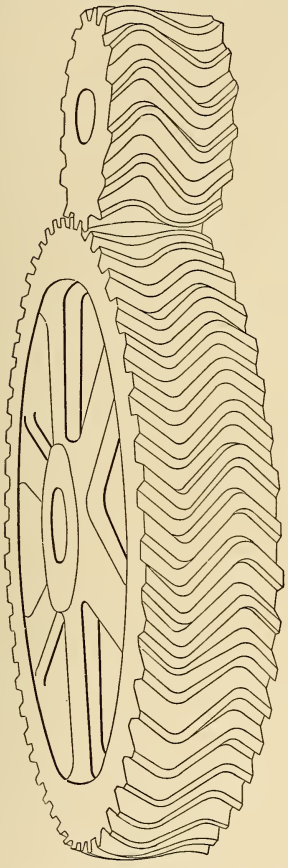


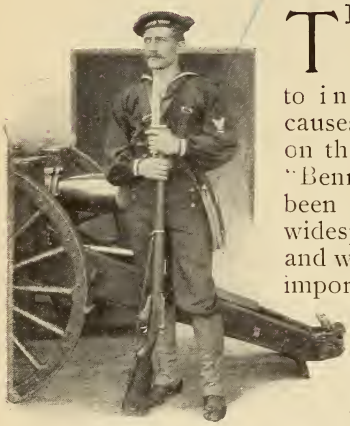
FIG. 22.—HELICAL GEARS SHOWN BY MESSRS. CITROEN, HINSTIN & CIE., PARIS

The woodworking machinery exhibit is a large one. Here, too, the growing complication of design may be noted. A universal machine by Kirchner & Co., of Berlin, may be instanced. It is primarily a band saw, but is really a combination, including a fret saw, a circular saw of rising and falling type to be drawn down below the table when not required, a moulding cutter, a horizontal boring spindle, and a vertical spindle, each with all the adjustments, holding devices, etc., peculiar to itself.

Perhaps the most striking feature of machine tool shown at the exhibition lies in the evidence of progress in grinding processes, the many novel machines for performing which are new to most people, although their prototypes have existed for some time in less ambitious forms. The stiffening up of so many of the lathes for operating with high-speed steels is another sign of the times; curiously enough, the first inkling of this was apparent at the Paris Exhibition of 1900, when the Taylor-White steel was shown in use. The effects upon design are now very obvious in the stiffening up of framings, increased driving powers, and better means of getting feeds, almost universally with sets of gears in preference to belt drives. The other machines, milling, planing, shaping, etc., also join in this general strengthening improvement.

THE ENGINEERING PERSONNEL OF THE UNITED STATES NAVY

By William Ledyard Cathcart, Late Chief Engineer, U. S. N.



THE report of the Court of Inquiry, convened to investigate the causes of the disaster on the U. S. Gunboat "Bennington," has been awaited with widespread interest, and will probably have important effects upon the future of the naval engineering personnel This may well be, since this accident seems to be, in its origin, without parallel in the history of the navy. In its tragic results, it has been compared with the bursting of the great gun, "Peacemaker," on the "Princeton" in 1844, and with the sinking of the battleship "Maine" in Havana horbor, but these events were not due to the deplorable laxity and negligence which, in this case, it is charged, sent three-score men to death in broad daylight on a man-of-war at anchor in a home port.

The "Bennington" is about fourteen years old, her engines and boilers being those originally installed. She is a twin-screw gunboat of 1700 tons displacement and 3400 horsepower, having four single-ended, three-furnace boilers of the low cylindrical type, each 17 feet 9 inches long and 9 feet 9 inches in diameter, set end to end, with two athwartship firerooms. On July 21, while in the harbour of San Diego, California, one boiler exploded and was forced aft upon another which, in turn, burst. The piping connections of the boilers were thus broken and a cloud of steam, carrying scalding water and hot ashes, filled the ship, killing 62 men and injuring 40 more, out of a total ship's company of 197. The report of the Court of Inquiry, as published, states in part:—

"The court is of the opinion that the explosion was caused by excessive steam pressure in boiler *B*, which came about first by shutting the valve connecting the boiler with the steam gauge, instead of the valves on the air-cock alone as was intended, so that the steam gauge did not indicate the pressure in the boiler; second, by unusual and heavy firing in the boiler to get up a pressure which the gauge failed to show; third, by the failure of the sentinel and safety valves to lift at the pressure for which they were set, and the pressure increased without relief until it was beyond the strength of the boiler, which gave way in its weakest part, afterward found to be the corrugated flue of No. 2, the lowest or middle furnace, which collapsed."

A second-class fireman, it appears, closed the wrong valve and an acting water-tender and chief machinist's mate, whose duty it was, failed to observe the useless steam gauge, while the firing went briskly on until, with inactive safety valves, the pressure rose beyond the danger limit in a boiler known to be somewhat weak from age. These three enlisted men were among the dead. The court, it is stated, recommended that the chief engineer, a young ensign, be tried by court-martial for neglect of duty in failing to see, in his own person, that the safety valve was kept in good working order and in failing to cause the safety and sentinel valves

to be tested, in accordance with naval regulations.

It is difficult to speak with moderation of such engineering as this. If the published reports are correct, neglect, blind to consequences, and, later, ignorance or carelessness, amazing in extent, blew up the "Bennington." The only reasonable explanation seems to be that the men who thus failed in duty lacked knowledge of the death-dealing qualities of a boiler thus mishandled. It seems a case of engineering children playing with edged tools. In view of the fundamental and essential responsibility of a commanding officer for the efficiency of his ship in all departments, and of the further fact that, since the enactment into law of the Personnel Bill of 1899, naval engineering is now one of the many duties of American line officers, the Secretary of the Navy has not only ordered the court-martial of the ensign in charge of the machinery, but that also of the commander of the vessel, the latter on the ground that, as press reports state, "the proof tends strongly to show that the enlisted force of the engineering division had been permitted to fall into habits of laxity and inattention in the discharge of their duties." The captain of a war vessel to-day is, in one sense, but the head of a great engineering plant for whose efficiency he is as fully responsible as Nelson or Decatur was when in command of a sailing ship of their time.

In justice to the officers thus facing court-martial, it should be said that no one who understands the present status of engineering in the United States Navy will be likely to believe them incapable, in general, or negligent with full knowledge. The failure seems primarily that of a system, and appears to be due to a lack of appreciation by many officers of the imperative need of expert engineering skill and unremitting care, if the ship is to be saved from disaster. When the "Bennington" made her first cruise, her machinery was doubtless in charge of a chief engineer of long service, with one or two commissioned engineer officers as his assistants, and with a full staff of machinists for watch duty. That now a single young ensign, whose engineering experience must have been most limited, should be detailed to replace this entire staff, may have been made necessary by present naval conditions, but is, from a technical viewpoint, absurd. The responsibility of the commanding officer in this case is, of course, general only. It is stated also that he had issued orders that the steam pressure should not exceed 135 pounds, the designed pressure having been 160 pounds.

The Personnel Act, which it seems now somewhat fashionable to deride, conferred some unquestionable benefits upon the United States Navy in increased pay, a steady flow of promotion, and in ending, for the time at least, the bitter strife between the Engineer Corps and the Line. But it laid upon the latter the burden of maintaining, in full efficiency, the engineering department of the navy. The act did not intend that, to attain other worthy ends, the vital interests of naval engineering should suffer, that the strength of the fleet should be impaired, and the safety of war vessels be hazarded to secure pay, promotion, and peace; and yet, while there is no question of the honour and sincerity of the board of line and engineer officers whose conclusions led to the Personnel Act, the "Bennington" disaster is not the only indication that, since it passage, the interests of naval engineering have suffered and the machinery of American war vessels has deteriorated. Under its provisions, and with the lapse of time, many of the officers of the former Engineer Corps have been placed upon shore duty or on the retired list, and there are now far too few in active service to deal effectively with the present situation.

Some causes of these unfortunate results seem to be lack of apprecia-

tion of the fact that the profession of marine engineering is far too extended and complex to be followed with success by officers who are not keen students of its many needs and swift advance, and, further, that engineering duty seems unwelcome to the majority of Line officers. The editor of "The Army and Navy Journal" says:—

"The young Line officer, detailed to the engine room, too often feels that it is an unpleasant detail, to be gone through with merely because it cannot easily be avoided. His ambition and interests are in the Line. He has a natural desire for command and, for that reason, it may be that, in some cases, he performs his engineering duty in a listless, perfunctory manner and without that enthusiastic interest which is the first condition of efficiency."

A contributing cause is, doubtless, the lack of officers. With the rapid increase of the fleet, the personnel has not kept pace. Rear Admiral Chadwick says:—

"The last report of the Chief of the Bureau of Navigation gives a total of 188 vessels in the United States Navy with a necessary complement of 2078 Line officers. This, to quote the words of the official document, 'shows the officers that would be required for sea service on the outbreak of war, when every available vessel would be required for active service; but it does not provide for officering the auxiliary vessels—whose number cannot be stated—nor for the details on shore in connection with the equipping, refitting, and supplying of the fleet and other necessary work.' * * * There are in the last 'Register of the Navy,' issued January, 1905, 1064 Line officers, only half the number needed now. * * * It will be a considerable time, probably ten years at least, before the Line officers reach as many as 2000."

Both the present Chief of the Bureau of Steam Engineering and his predecessor, Rear Admiral Melville, have called attention officially to the danger from existing conditions. The effect of the scarcity of officers, Rear Admiral Rae, the Engineer-in-Chief, notes in his report of October 1, 1904. He says:—

"There is no doubt that an insufficient quantity of engineering duty has been performed by the younger Line officers to properly qualify them for filling the higher engineering positions at sea. The cause is well known,—a lack of officers. If no other way can be found, it would be to the advantage of the country to place out of commission the requisite number of vessels now in service, in order to obtain the officers for this vital necessity. The lack of experienced men is felt in a great many vessels, as shown by numerous reports received."

In the present and—from the quotations just given—probably continuing absence of a sufficient number of commissioned officers for engineering duty, the condition of the corps of warrant machinists seems to merit congressional action and relief, since the importance of their service in watch-duty is beyond question.

These officers have duties similar to those of assistant engineers in the merchant marine, but their field is wider and their responsibility far greater. They form, as a whole, a worthy and able corps whose services, since the passage of the Personnel Act, have been of much value to the navy, although they appear to have received but scant recognition, owing to the traditional prejudices of that most conservative of all services. Without these men, it is possible that recent naval history would have recorded more of such disasters as that on the "Bennington," yet their numbers are inadequate and they seem to have just cause for discontent.

There are but 180 warrant machinists, and their services are so essential that they are kept almost continuously at sea, although it is

customary to give all other officers of all ranks shore duty between cruises, if the exigencies of the service do not prevent. Again, the boatswains, gunners, and carpenters are, by existing law, the only warrant officers who are eligible, after six years' service, for commissions as "chief" in their respective grades, "to rank with, but after, ensigns," and receiving increased pay. There are now 76 warrant machinists who, by length of service at least, would be eligible for this promotion, if the law, through oversight or intention, had not failed to include them.

Again, the warrant machinists are, in by far the most important part of their duties, not machinists at all, but "engineers of the watch" with, in this, practically the same responsibility as commissioned watch-officers once held. In view of this important duty and of the naval regulation that all warrant officers shall take precedence according to date of appointment, the alleged discrimination, in the assignment of quarters on board ship, against warrant machinists and in favour of boatswains, gunners, and carpenters, is manifestly unjust.

With a fleet growing so rapidly as that of the United States and an attendant scarcity of Line officers which, as has been shown, may continue for ten years or more, it is evident that the warrant machinists form, and will form, as watch-officers, a very important factor in the engineering efficiency of the navy. The disadvantages under which they now labour and which retard the healthy growth of the corps may be traced directly to the prejudices of the age of sail. The sea-pay of warrant machinists is fair, ranging between $1200 and $1800 per year; their duties, within their sphere as watch officers, are of grave responsibility in their bearing upon the safety, speed, and offensive qualities of warships. If the corps were as it should be, one of Line officers of warrant rank, with a reasonable prospect that its abler members might eventually pass onward to commissioned rank, its disabilities would be removed and there seems little doubt that it would attract from civil life a class of well-equipped young men whose attainments would fit them for such possible advancement and who would, meanwhile, extend the well-proved efficiency of this corps.

A problem, however, which is far graver, and of vital importance to a modern navy, is that of an adequate supply of trained officers for professional engineering work, in skilled supervision on shipboard, and in designing and construction on shore. The record of the former Engineer Corps is, in this, without superior, and probably without equal, in naval history, and this standard must be maintained, if the strength and efficiency of the fleet are to be preserved. These ends can be attained only by the able and zealous service of officers when assigned to engineering duty. If it is possible, as has been suggested, that Line officers have, as a rule, a tendency to perform that duty in a "listless, perfunctory" manner, and if, by suitable regulations, this tendency cannot be removed, it is apparent that "amalgamation" has failed. In that event, there is a growing belief that the most effective solution may be the formation of a corps of Line officers for engineering duty exclusively, or one of engineer officers having positive rank and lineal titles, either corps to be recruited yearly by Annapolis graduates in sufficient numbers to maintain it at full strength. By the gradual adoption of such a system and by the increase in number and proper recognition of the warrant machinists, the exigency due to lack of officers might possibly be met and the former high standard of naval engineering restored. In any event, a prompt and effective settlement of this question seems to be, by far, the most pressing need of the fleet.

MODERN BRITISH HIGH-SPEED STEAM ENGINES

By Leo H. Jackson

PART III.—MORE EXAMPLES OF CURRENT PRACTICE

Part I, in the August Number, was Devoted to a Discussion of the Typical Features of Engines of this Class, and Part II, in the September Number, to Examples of Current Practice, which are continued in this Issue.

THE ALLEY & MACLELLAN ENGINE

Messrs. Alley & Maclellan, Ltd., of Glasgow, are makers of the "Sentinel" high-speed engines with forced lubrication. Two of their leading types, viz., a compound single-crank (tandem) from 3 to 35 H. P., used principally for driving centrifugal pumps, fans, and for ship lighting, and a triple expansion, three-crank engine, from 250 to 1000 H. P., are shown in Figs. 12 and 13. They also make a compound two-crank engine.

Very similar in appearance to the triple expansion design is the three-crank compound, made from 200 to 1000 H. P., with low-pressure cylinders each of half the usual volume, with the cranks at 120 degrees. The illustration of the triple-expansion class is taken from an engine of 750 H. P.

Messrs. Alley & Maclellan are firm believers in the principle of separating the cylinders and providing each with its own steam chest and piston valve. Mention has already been made of the reasons which lend weight to this disposition of the steam-heated surfaces, viz., the avoidance of unequal expansion of the metal of the cylinder casting from widely different temperatures occuring in the same valve chamber, tending to distortion and leakage at the single-piston valve, together with the transfer of heat from the incoming steam to the exhaust—inevitable when the two are passing through the same valve. Mechanically speaking, the advantages of separated steam-chests are that the cranks are brought into close proximity, a better balancing action being thus obtained, and further, the two valves, driven each by its own eccentric, can be adjusted independently to give the best results in individual cases.

Generally, the construction of the "Sentinel" engines accords very closely with the detailed description of our typical engine.

The triple-expansion engines are provided with Alley & Maclellan's special device for heating up before starting. By this means steam at boiler pressure is admitted to all three cylinders simultaneously, and has access to every part of the cylinders and valve-chests without the necessity of barring the engine round to get the steam through.

It also provides perfect automatic drainage for the cylinders, so that an engine may be started up in a very much shorter time than is usually possible, while the danger from the destructive effects of water-hammer is eliminated.

At a small extra cost an appliance can be fitted to the governors of compound and triple engines, for automatically taking direct steam to low-pressure and intermediate cylinders during temporary overloading; otherwise, this is provided for by the ordinary hand-operated by-pass arrangement. Messrs. Alley & Maclellan give the following tabulated re-

sults obtained from compound and triple engines:—

Two-crank compound type, 50 KW., or 75 B. H. P., with a steam pressure of 140 lbs. and 25-in. vacuum, no superheat.

Load	Full	¾	½	¼
Pounds steam per B.H.P. hour	19.25	20.1	22.2	25.5
Mechanical efficiency...	93 %	91 %	87 %	78 %

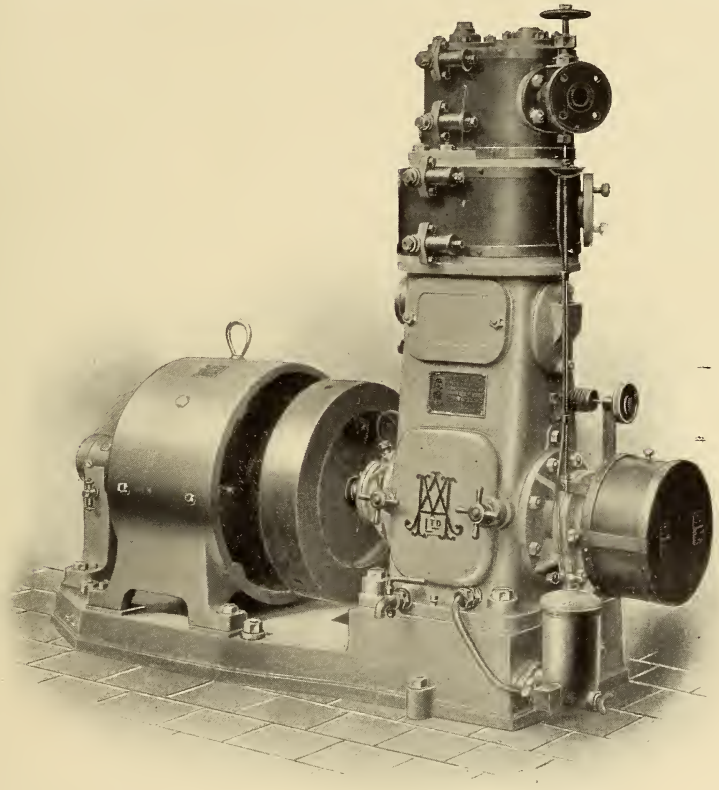


FIG. 12.—A TANDEM COMPOUND, SINGLE-CRANK ENGINE, BUILT BY MESSRS. ALLEY & MACLELLAN, LTD., GLASGOW

Three-crank triple-expansion type, 330 KW., with a steam pressure of 190 lbs., superheat 50 degs. F., vacuum 25 ins.

Load	Full	¾	½	¼
Pounds per K. W. hour	21.1	21.9	23.5	28.6
Pounds per electrical H. P.	15.75	16.35	17.52	21.35
Pounds per I. H. P....	13.4	13.65	13.9	14.9
Combined efficiency...	85 %	83.5 %	79.3 %	70 %

THE MATTHEWS & YATES ENGINE

Messrs. Matthews & Yates, Ltd., of Swinton, Manchester, are makers in particular of a class of single-cylinder, forced-lubrication engines, intended in the first instance for driving their well-known induced-draught fans, and also for dynamo sets of their own make.

These engines have proved so successful in the service for which they were designed that they are manufactured and offered as a standard series for outside purposes, and from a careful scrutiny of the specification the writer believes that they will rank with the best.

Generally speaking, the construction is almost exactly as described in the opening pages of this article. The piston valves are ground and lapped to fit the bores, and rings of steel, cast-iron, or bronze, are fitted as required, and in all cases the valve connection is a floating one, the valve being free to find its own center. The pistons are of forged steel,

and the bearings are of a mixture known as Mattock metal, and, if desired, the crank brasses are lined with white metal. The packing of piston-rods and valve-spindles is metallic.

The interior of bed-plate and casing is coated with white enamel specially prepared to withstand the action of hot mineral oil, with the double view of fixing any loose sand on the surfaces, and of improving the light for inspection of the working parts. The main bearing caps are of steel, and the crankshaft has the oil-throwers forged in one with it, the part upon which the fly-wheel is fitted being enlarged for that purpose. The governor is of the throttle type, direct-driven from the crankshaft, and can be adjusted to give a large variation in speed while the engine is running, giving close regulation of speed through the range.

The speed can be controlled within $1\frac{1}{2}$ per cent. under sudden variations of load, from nothing to full, and vice versa, with a momentary

SPEEDS AND POWERS OF ALLEY & MACLELLAN ENGINES

Diameter of Cylinder, Inches	Stroke, Inches	Revs. per Minute	B. H. P., 150 Lbs. W. P., Condensing	B. H. P., 150 Lbs. W. P., Non-Condensing	Size of Steam Inlet, Inches	Size of Exhaust Outlet, Inches
5	4	600	22	19½	1½	1¾
5	4	500	18	16	1½	1¾
5	4	400	14½	12¾	1½	1¾
5	4	300	10½	9¾	1½	1¾
6	5	600	39½	35	1⅞	2¼
6	5	500	32½	29	1⅞	2¼
6	5	400	26	23	1⅞	2¼
6	5	300	19½	17½	1⅞	2¼
7	6	600	65	57	2¼	2½
7	6	500	54	47½	2¼	2½
7	6	400	43	38	2¼	2½
7	6	300	32½	28½	2¼	2½
8½	7	450	84	75	2½	2¾
8½	7	400	74½	66½	2½	2¾
8½	7	350	65	58	2½	2¾
8½	7	300	56	50	2½	2¾
8½	7	250	46½	41½	2½	2¾

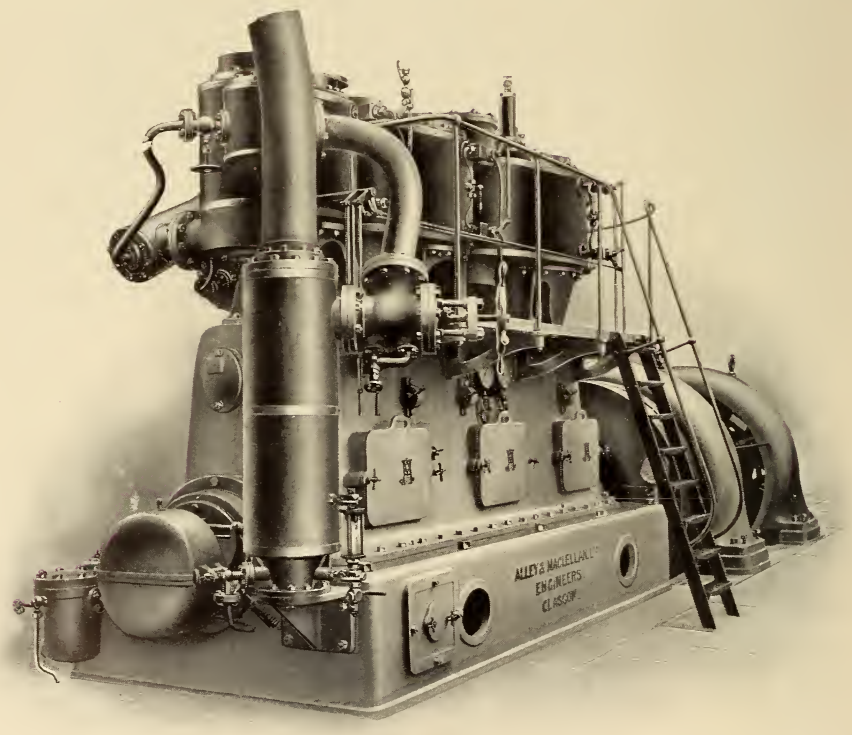


FIG. 13.—A TRIPLE EXPANSION, THREE-CRANK ENGINE, BUILT BY MESSRS. ALLEY & MACLELLAN, LTD.

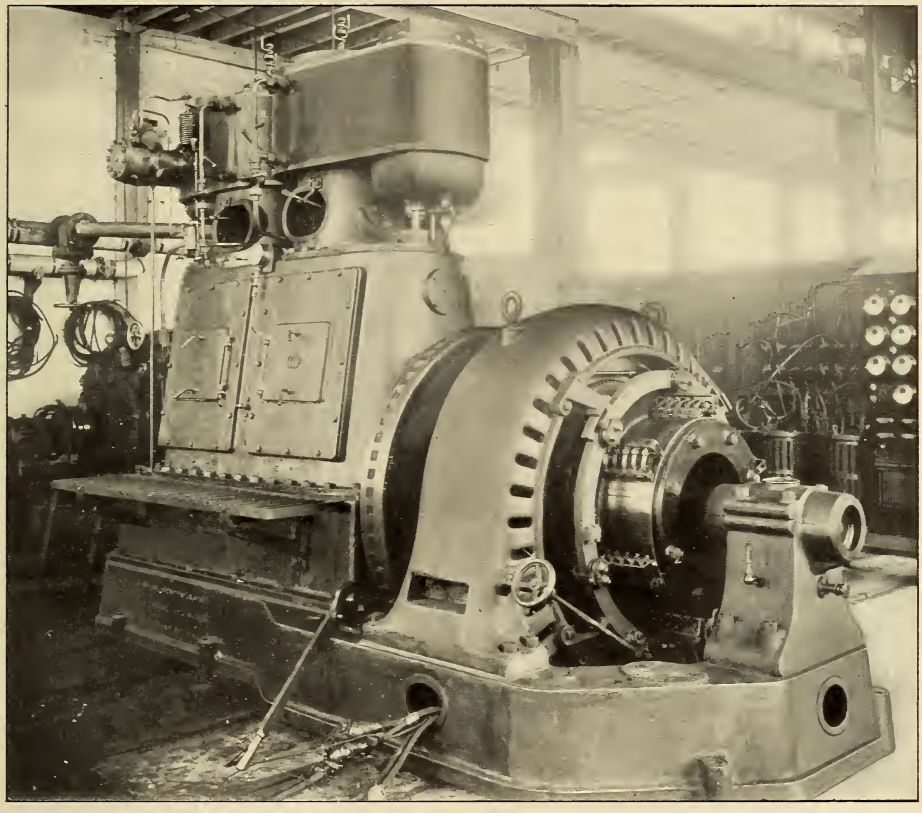


FIG. 14.—A TWO-CRANK COMPOUND ENGINE BUILT BY MESSRS. CLARKE, CHAPMAN & CO., LTD., GATESHEAD-ON-TYNE

increase of 5 per cent. when the full load is suddenly removed. The maximum working steam pressure is 150 pounds, and the speeds and powers of the standard sizes are as given in the preceding table.

Compound engines, and engines of larger size than those specified above, are made by Messrs. Matthews & Yates, Ltd., when required, to special order.

THE CLARKE, CHAPMAN & CO. ENGINE

Messrs. Clarke, Chapman & Co., Ltd., of Gateshead-on-Tyne, build forced-lubrication engines of the single-cylinder and two-crank compound types. The sectional view of the latter, given in Fig. 15, shows an engine with $\frac{18 + 27\frac{1}{2}}{12}$ inch cylinder, designed to run at 315 revolutions per minute, and, with 180 pounds steam pressure, to develop 400 brake horse-power when exhausting to atmosphere.

Here we have another variation in design for the cylinders, though with independent steam-chests, are cast in one piece, and with them the frame, or distance-piece, by the lower flange of which the whole is attached to the casing or body of the engine. From the point of view of the purchaser there can be no objection to this arrangement, save that in the possible event of accidental damage to any part needing replacement of the whole casing, the cost would be heavy as compared with the usual construction where the cylinders, though apparently in one, and cov-

ered by a continuous lagging of sheet steel, are in reality cast separately, and not even bolted together in any way. Probably, however, the makers consider that the great strength and rigidity imparted to the cylinders by this system is worth the additional expense in manufacturing. It seems almost ungrateful to regret that the makers did not go a bit further, and cast the guide-trunks also in one with the bottom flange. The truth and alignment of cylinder liners, and kept at their proper relative distance apart by steel ferrules on the valve-spindles.

The crossheads are forged in one with the piston-rods, and contain the unusual feature of a wedge adjustment for the small-end brasses. This construction necessitates the use of a loose crosshead-pin, which is fitted to the connecting rod fork-ends by a taper head at one end and a loose taper ferrule at the other, so that the nut tightens the pin in all ways.

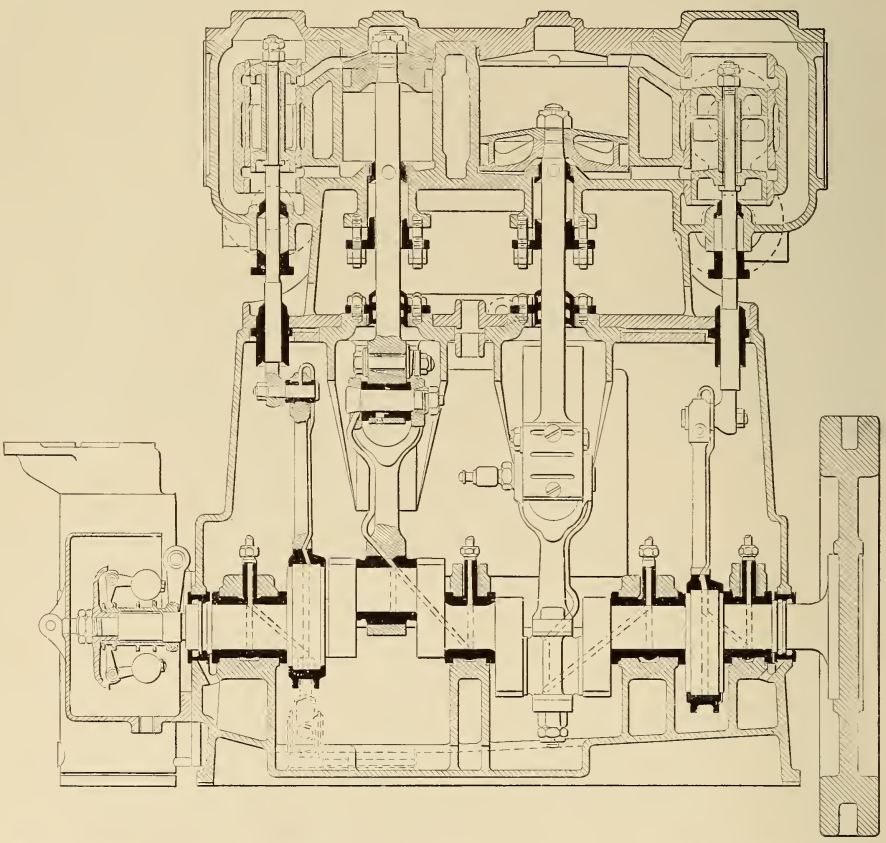


FIG. 15.—SECTIONAL VIEW OF TWO-CRANK COMPOUND ENGINE BUILT BY MESSRS. CLARKE, CHAPMAN & CO., LTD.

bores, guides, and stuffing-boxes, would then have been almost automatically ensured.

The pistons, of cast steel, are fitted with cast-iron rings, and the valves are simply plain pistons, without packing rings, working in forced-in The stud, seen on the low-pressure crosshead-pin, and the vacant hole in the casting above it, are for attachment of indicator gear when required.

Owing to the back-to-back arrangement of the cylinders, the

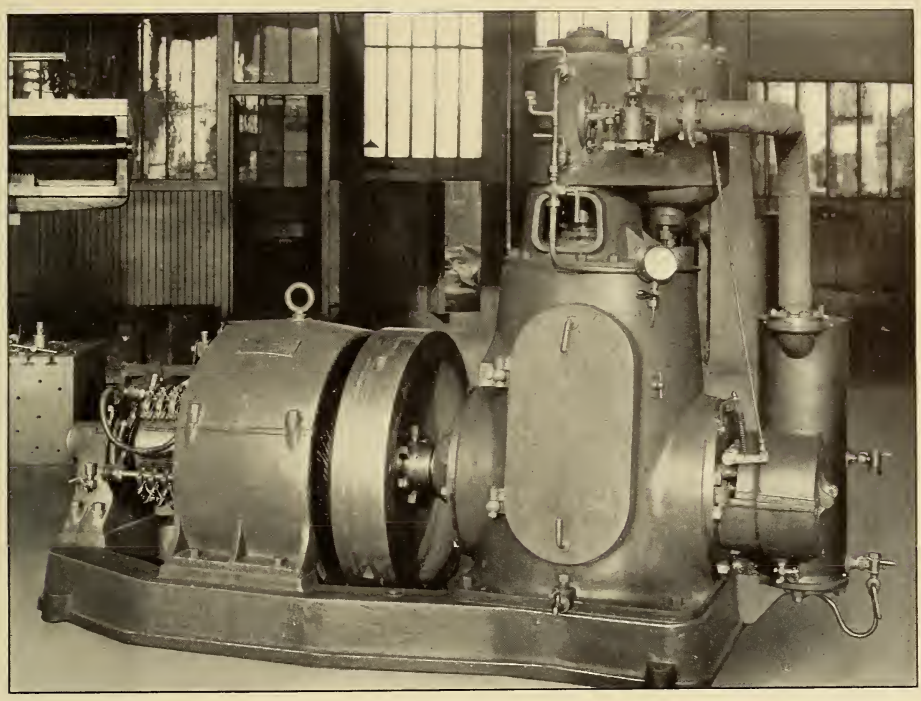


FIG. 16.—A SINGLE-CYLINDER, DIRECT-CONNECTED SET BUILT BY MESSRS. CLARKE, CHAPMAN & CO. LTD.

cranks, which are, of course, not fitted with counter-balance weights, can be placed at a minimum distance apart, thus almost eliminating the rocking couple, and producing, we should imagine, a very steady-running engine at the highest speeds. The bearings throughout are of gun-metal instead of the usual cast-iron with white metal lining.

In the valve motion, the eccentric sheaves are of cast steel, with gun-metal straps, wrought-iron rods and steel valve stems, these latter being enlarged to form plunger guides, working through gun-metal bushes in the lower flange of the distance-piece. The connection of the eccentric rods with the valve stems is a one-sided or wrist pin joint, as owing to the position of the bearings, these rods are relatively out of line. The joint, however, is a substantial one, and subject, of course, to the forced lubrication. The oil pump is of the usual valveless type. The speed is controlled (specified within 3 per cent.) by a governor in the usual position on the end of the crank-shaft, actuating the throttle valve through bell crank levers, and a long inclined coupling-rod. There is the usual adjustment for varying the speed while the engine is running.

Clarke, Chapman & Co.'s single-cylinder engine is almost identical in its arrangement with the high-pressure side of their compound engine, and the foregoing description is generally applicable to it.

We are glad to note the provision of a substantial separator in each case, and the equipment includes, besides all the usual fittings of indicator-connections, drain-cocks, sight-feed lubricator, tachometer, oil-pressure gauge, barring-lever, etc., "a sounding-rod" for testing the depth of oil in the bed-plate.

THE DAVEY, PAXMAN & CO. ENGINE

Messrs. Davey, Paxman & Co.,

Ltd., of Colchester, are makers of compound and triple-expansion enclosed engines of all powers, with forced lubrication. The particular engine illustrated in Fig. 17 was made by them for the Paisley Corporation Electricity Works, for traction work. It was built to carry a normal load of 500 kilowatts, continuously at a speed of 240 revolutions a minute, and is capable of taking a momentary overload of 50 per cent., or a 25 per cent. overload for a period of two hours. The steam is supplied at 160 pounds pressure, with a superheat of 150 degrees F.

The builders adhere to the principle of separate cylinders, each with its own valve-chamber and piston valve, in all their engines, with the exception of the smaller sizes of compounds.

As the general construction of their engines follows very closely the standard type, we need here concern ourselves only with the firm's specialties. The piston-valves, with the object of increasing the effective area of the port openings, are made under Paxman's patent, with a stationary central stalk having ports formed in it exactly similar to, and coincident with, the main steam ports. The steam being admitted centrally, the inner edges of the piston valve effect the cut-off and the packings of the valve-spindles are thus exposed only to steam of the exhaust pressure proper to their respective cylinders. The clearances are specially looked after, the top and bottom covers being carefully turned to match the pistons so as to reduce the waste room to the minimum safe allowance.

The double-seated throttle valve is specially designed to avoid the sucking action of the steam, and a very large steam separator is provided with the same object. As a result, the governing is very accurate, the

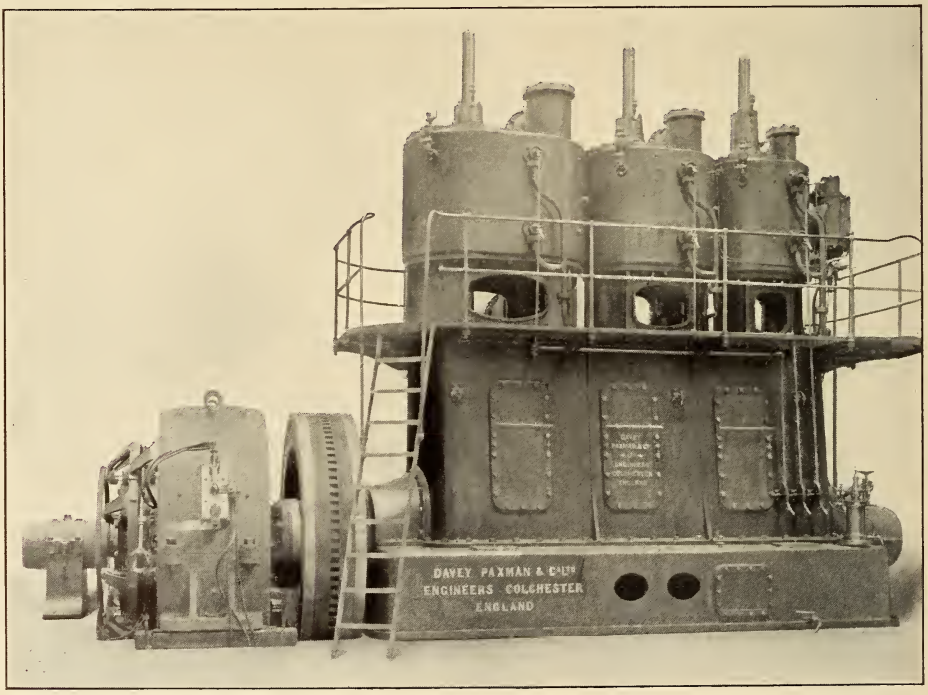


FIG. 17.—A TRIPLE-EXPANSION ENGINE WITH FORCED LUBRICATION, BUILT BY MESSRS. DAVEY, PAXMAN & CO., LTD., COLCHESTER, DIRECT CONNECTED TO A 500-KW GENERATOR

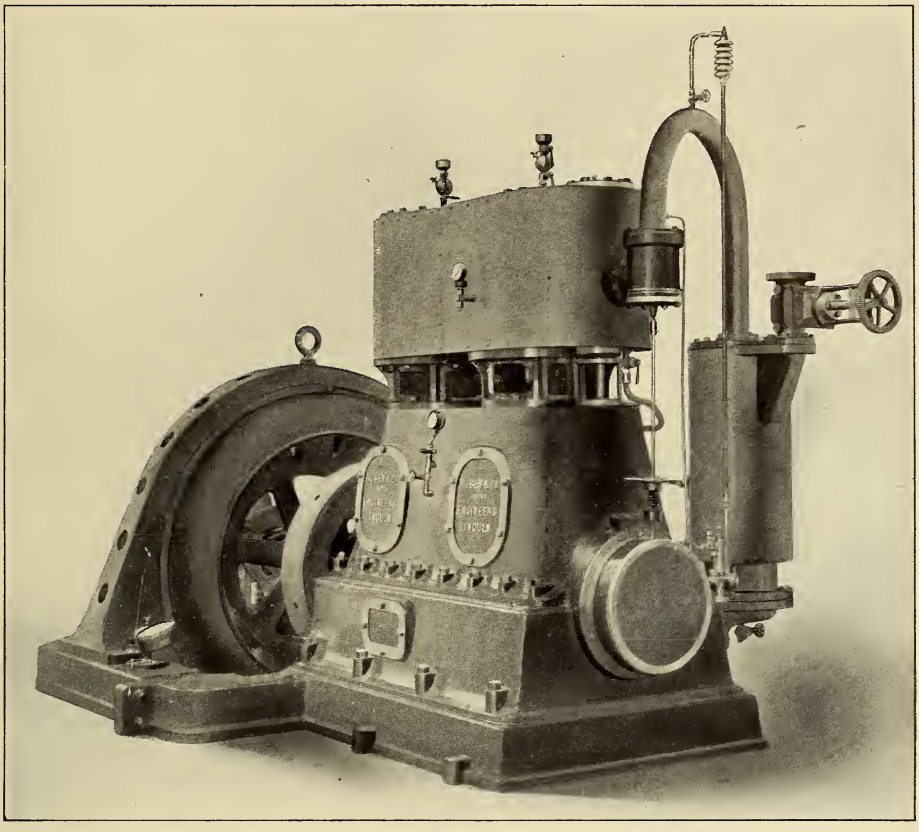


FIG. 18.—A COMPOUND TWO-CRANK ENGINE BUILT BY ROBEY & CO., LINCOLN, COUPLED TO A GENERATOR

permanent variation, with full load suddenly thrown on or off, being within 2 per cent. at all speeds within the range of the adjuster, say 5 per cent. above and 5 per cent. below normal.

The disc fly-wheel is accurately balanced, and is forced on to an enlarged part of the crankshaft. There are two oil-pumps, both driven from the intermediate eccentric strap, of the usual valveless type, supplying oil to all the moving parts, under a pressure of 20 to 30 pounds per square inch.

All the levers and handles for operating the engine are brought to one point, and all the steam and vacuum gauges also are placed well in view of the driver. A commodious platform surrounds the cylinders, and, in general, things are made as convenient and comfortable for those in charge as possible.

THE ROBEY ENGINE

Figs. 18 and 19 show one of the 8-inch stroke compound two-crank engines built by Messrs. Robey & Co., Ltd., of Lincoln. The cylinders, though apparently in one piece, are in reality separate, each with its own valve chamber, and piston-valve. The design throughout is very much in accordance with the lines laid down in the writer's preliminary observations upon this class of engines. The four steps or ledges turned on the external surface of the piston-valve-liners are plainly shown, as also are the long screws securing the liner firmly endwise, while allowing

lateral expansion. The course of the oil-circulation through pipes and perforations in the crankshaft and crosshead-pins is very distinctly given.

The small circular drum, or pulley, for the indicator motion, worked by a double-jointed rod from the low-pressure crosshead, and serving for both cylinders, is worthy of attention. Messrs. Robey state that that they make a full line of sizes in this class, and, as we can see for ourselves, their design is fully up to the latest practice. The cranks are not counter-weighted. Fig. 19 also illustrates the arrangement of "oil-thrower," seen next the flywheel, consisting of a convex disc fitted to the boss, for spinning off the oil which flows out through the main bearing. A circular casing around this collects the oil thrown off, and drains it back again into the bed.

Messrs. Robey also make another class of enclosed vertical engine with forced lubrication. This design, shown in Fig. 20, is only used for the larger sizes, and in this both cylinders are fitted with Corliss gear. Messrs. Robey state that both the pistons' speed and the speed of rotation in these engines are very high. They are of simple and massive design, and, though evidently of longer stroke, proportionately to diameter, than the majority of the engines here dealt with, they come fairly under

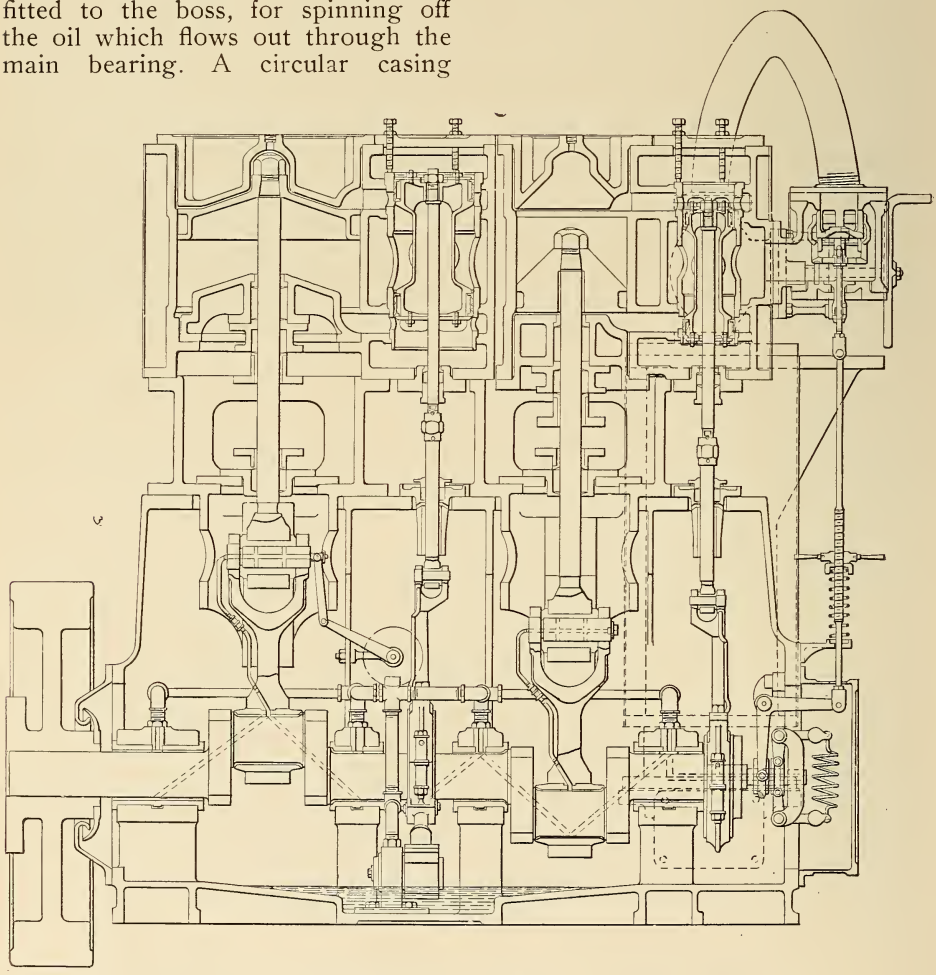


FIG. 19.—SECTION OF COMPOUND ENCLOSED ENGINE BUILT BY MESSRS. ROBEY & CO. LTD.

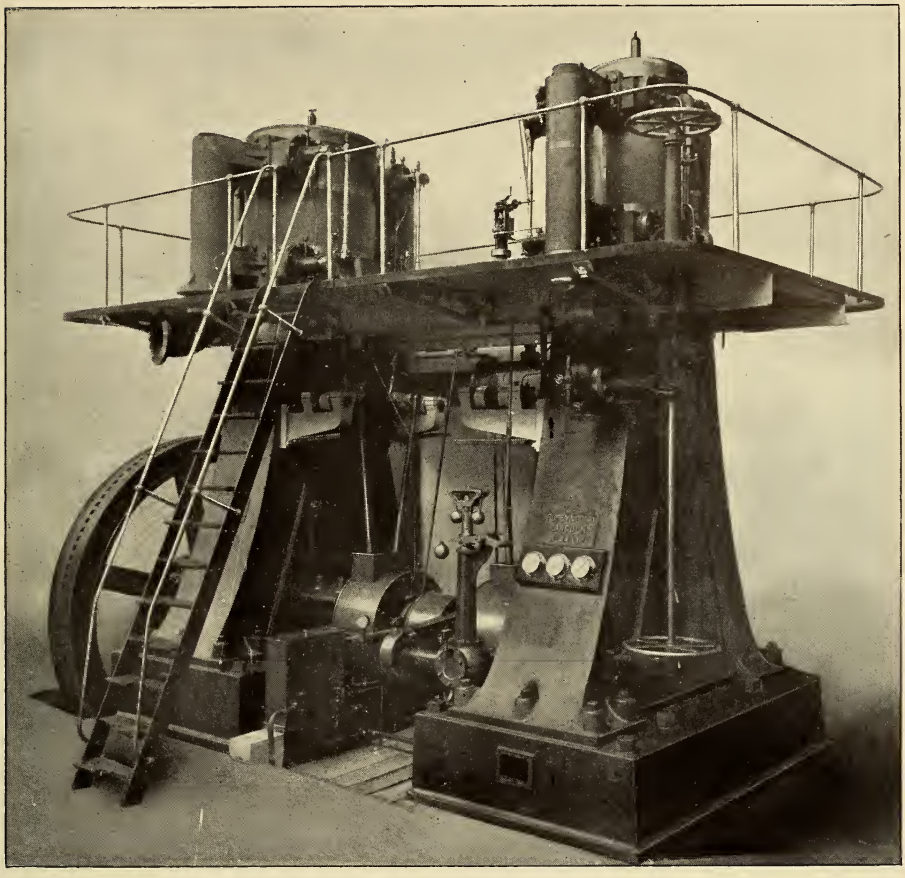


FIG. 20.—A LARGE HIGH-SPEED COMPOUND ENGINE WITH CORLISS VALVES AND FORCED LUBRICATION. BUILT BY MESSRS. ROBEY & CO., LTD.

the designation of high-speed, forced-lubrication engines.

THE BROTHERHOOD ENGINE

Mr. Peter Brotherhood, of Belvedere Road, Westminster Bridge, S. E., is, the writer believes, the only London manufacturer of forced-lubrication engines. A long list of His Majesty's more recent battleships and cruisers which have been fitted with Brotherhood engines for electric lighting purposes leads us to expect a very high degree of excellence, and, as we shall presently see, the Admiralty's choice is sufficiently justified.

Mr. Brotherhood's patterns include single-crank, simple and tandem engines, two-crank compounds, and three-crank triple-expansion engines. All these are rated for power by the diameter of the low-pressure cylinder, the diameters of the high and intermediate cylinders being variable and dependent upon the available steam pressure and other special conditions of each case. The steam consumption per H. P.-hour (brake or electrical) of every engine is carefully ascertained before delivery, the results are recorded and copies are furnished to customers, who are invited to witness the test themselves. It is specially mentioned that "no special refinements are introduced in order to attain trial results, which cannot be repeated in ordinary work,

or which would tend to mislead and cause disappointment."

The two-crank compound engine shown in Fig. 21 is built on the lines of our typical standard engine. We need, therefore, notice only the special features of the Brotherhood engines.

The high-pressure piston-valves are solid, and are ground and lapped to fit the valve bores, the low-pressure valves being fitted with hard, close-grained spring rings finished and removed without lifting the crankshaft.

The internal surfaces of the casing and bed-plate are very carefully cleaned and then painted with several coats of white enamel specially prepared to resist the action of hot mineral oils. This locks up any remaining particles of sand or grit, and facilitates the inspection of the interior by improving the lighting. Those who have suffered from the effects of foundry sand lurking in

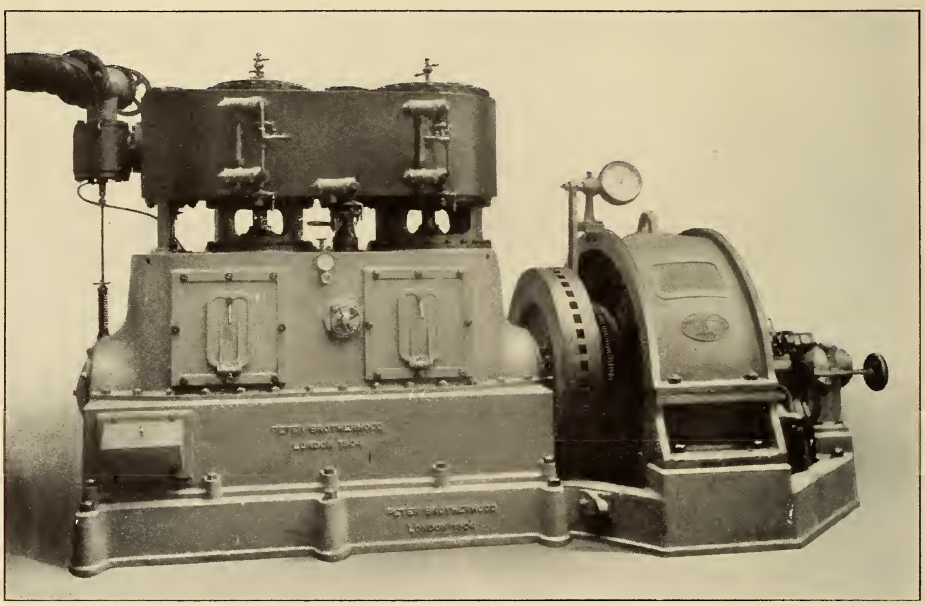


FIG. 21.—A TWO-CRANK COMPOUND ENGINE BUILT BY PETER BROTHERHOOD, LONDON, COUPLED TO A 105-KW. GENERATOR TO RUN AT 400 R. P. M.

by grinding to standard sizes. The eccentric straps are of bronze, with forged steel rods, and joint-pins hardened and ground, working in phosphor-bronze bushes. Each piston-rod is of annealed forged steel, and both rods and slippers are finished on dead-center grinding machines, to ensure perfect truth. The crankshafts are annealed after being rough-turned, and are of the highest quality of acid open-hearth steel. The main bearings, held down by steel caps, are of gun metal, lined with white metal, and can be turned out

inaccessible crevices, and from time to time washed out by the powerful solvent continually sprayed over the internal surfaces, will appreciate the pains displayed to obviate this.

There are two strainers to each pump, so arranged that while either is out for cleaning, the whole of the oil passes through the other one on its way to the pump.

We may note in conclusion that Mr. Brotherhood recommends the use of a separator when there is any liability to priming in the steam supplied.

CONCLUDING REMARKS

As will have been gathered from the foregoing, the writer's aim has been, after a preliminary dissertation upon the general characteristics of the engines, to review briefly the particular features of each of the leading makers' productions. While the actual differences in design are so small relatively as to argue a common origin, yet each maker has built up his trade upon lines of his own. Thus, central-station lighting plant has been the objective of one firm; electric traction work has become the specialty of another, while motive power for fans or centrifugal pumps has been the branch most affected by a third; ship lighting, or Admiralty work, by others, and so on.

The reason for this is, of course, that existing makers of various classes of machinery requiring high rotational speeds, have not been slow to grasp the advantages of the quick-speed, forced-lubrication engine, and have commenced its manufacture with a particular view to their own specialty. It has been most interesting also to note the differences in the way of presenting their information, exhibited by the various firms to whom the writer has been indebted for illustrations and descriptive matter.

As far as possible, he has endeavoured to reproduce, in abbreviated form, the special characteristics of each, and while he has not been able to refrain from a little gentle criticism here and there, yet he concludes his survey of this very modern type of prime mover as he began, with the conviction that in its own way, and for its own purposes, we have here one of the most striking examples of fitness in design and perfection of workmanship which the world of engineering has to offer.

THE PROVINCE OF THE INDUSTRIAL ENGINEER

By H. F. J. Porter

THE wonderful development that has taken place in the industrial world during the last twenty-five or thirty years has been so rapid that stable conditions have at no time been able to assert themselves. Particularly has this been true in the relations between employer and employee, which, gradually becoming abnormally strained, have finally reached a condition of open warfare with organized armies on each side.

It is this condition which, both sides now know, will be disastrous if long continued, and each at last realizing the justice of the other's cause, is willing to recognize that there are principles of right and wrong involved in the issue existing between them, which can no longer be neglected.

Controversies of this nature invariably reach an acute stage, which develops a suggestion for a cure. Reviewing the history of the growth of almost every industry which is now taking a prominent part in the world's progress, it will be seen that those individual enterprises which stand at the front have either escaped altogether from internal dissensions by the initial and constant application of certain fundamental ethical principles in their methods of management, or, having confronted a serious phase in their experience, have realized the importance of these same principles, and by their prompt adoption have diverted the threat-

ened disaster and passed on to conspicuous success.

The study of cause and effect in the lessons taught by these successful enterprises has demonstrated that the adoption of ethical methods in the management of business is not only morally right, but that it pays in a direct money way.

The United States Bureau of Labour, in its report for 1904, dwells especially on the increase in the number of manufacturing companies which are now encouraging "industrial betterment" in their organizations.

Teachers of political economy in colleges, leading clergymen, lawyers, and statesmen everywhere, are advocating the adoption of ethical principles in business dealings.

On these principles is founded the work which is the function of many industrial and civic betterment associations. Everywhere there is evidence of an ethical trend in affairs.

Large as is the number of concerns which have already signalized their acceptance of these ideas by putting them into practice, there is a still larger number which hesitates to act, not knowing how to go about effecting a change from old methods—not understanding what the movement really means—or fearing to entail what might be considered unwarranted expense. And yet these same concerns are daily appreciating more and more that their competitors who are more progressive in the movement are outdistancing them in the race for supremacy through their acquisition of the best element of employees in their organizations owing to the superiority of their working conditions.

The demand by these establishments for someone who has had experience in the work of industrial betterment who can lead them safely over snags and pitfalls which entail expense and threaten failure, has added to the province of the industrial engineer. It was he who had designed the buildings, laid out the power plant, purchased the equipment, built houses for the operatives, and made the completed enterprise an operating investment.

He has always known that the conditions under which men work must be good if good work is to be expected of them; that the light, the temperature, the quality of air in which work must be accomplished are factors in the character of work performed; that the sanitary conditions and appliances for safety from accident have an appreciable bearing on the product. The industrial engineer is acquainted with methods of obtaining cost of product and means whereby such cost can be reduced. There are also principles with which he is familiar by which the product itself can be simplified and improved. There are ways by which the sales may be increased, and the market broadened along lines which, having been repeatedly verified, are scientific. Now, however, competition of a novel type is affecting the interest on capital invested.

He must hereafter reckon more than ever with the human element in his organization. He must evaluate the essentials of the efficient employee, viz., health, character, and intelligence, and the best methods by which those features in his make-up can be fostered and improved. Knowing that a vigorous employee will do more work than one who is not well, the engineer must institute such methods in the system of management as will raise the physical condition of the working organization to a higher state.

Appreciating that the employee of high character is more reliable and does more honest work than he who is shiftless and spends his time outside of working hours in low pleasure, he must surround the organization with an atmosphere of improvement and uplift in which such an employee either naturally responds to the tonic influence or eliminates himself from the uncon-

genial environment. Recognizing that the employee differs from the machine at which he works in the possession of human intelligence, and that this characteristic can be improved by the encouragement of ambition and self-respect, there are certain well-defined and recognized methods of such accomplishment which he must make effective. The environment of the family at home must also be considered, for employees with minds divested of worry are capable of better work than those whose thoughts are otherwise diverted.

To do this with a spirit of honesty and fair dealing between man and man is the added province of the industrial engineer. It is a wide field thus opened to him,—one of great possibilities in the world of advance, in which industry is the leading exponent.

He should be alive to his responsibilities, which are both great and many, and yet he should not hesitate to seek for the opportunity to assume them, for his power for accomplishing good to humanity is enormously enhanced.

Current Topics

It has been pretty well dinned into the ears of almost everybody that electric incandescent lamps are likely to set on fire inflammable materials with which they are brought into close and prolonged contact,—paper shades, for example, textile fabrics in show windows, etc., and that accordingly their fire danger is a thing to be reckoned with. The fact that the light was not naked unfortunately in some cases gave it an air of security which, in reality, was lacking and led to accident. This has latterly been further emphasized by investigations conducted by one of the British Government inspectors of coal mines with incandescent lamps as used in underground coal workings. These investigations are said to have shown, among other things, that when a 16-candle-power lamp was covered with coal dust, the generation of heat was so rapid that within four minutes a temperature of 450 degrees F. was attained, and the bulb burst. In another case a 100-volt 16-candle-power lamp was imbedded in a heap of coal dust. Within three minutes smoke was emitted from the dust, and in another case where the lamp

was simply laid down upon the heap, flame burst out in the course of twenty-five minutes. Colliery managers, it is urged, should therefore impress upon the miners the great danger, when stopping work for a few minutes, which attends the laying down of the lamp upon the ground. It should always be suspended, with the bulb free from contact on all sides. Every care should also be taken in handling the globes so as to avoid breakage, as the instantaneous exposure of the incandescent filament when the bulb bursts may be sufficient to create a violent explosion should any firedamp be present. A recent disastrous explosion in a French coal mine is said to have been brought about by just such an occurrence.

Some interesting particulars regarding the use of refractory clay for the purpose of kindling fires are given by W. S. Blatchley, State geologist of Indiana, in a recent annual report. The clay is mixed with one-half of its bulk of sawdust, and is then moulded into an oval mass a little larger than a hen's egg, and with four grooves running lengthwise. The solid thus formed is then burned, and in the process of burning the sawdust is destroyed, leaving a porous mass of fire-clay of great refractoriness. A handle of copper wire is attached to this and the fire kindler is complete. When dipped into a can of coal oil and allowed to remain over night, it absorbs enough oil to burn for fifteen or twenty minutes, with a flame sufficient to kindle either coal or wood fires.

Maintaining a clear, fresh atmosphere in a building located in a district where smokiness and dust are conspicuously present, is an accomplishment of general interest. It appears to have been satisfactorily attained in the case of the office building of the H. K. Porter Company, locomotive builders, of Pittsburg, by the installation of a combined plenum heating system and an air-washing outfit, the entire equipment having been designed and put in by the B. F. Sturtevant Company, of Boston. The heating apparatus, consisting of a fan, heater, and belted motor, is located in the basement of the building in conjunction with the washer, which consists of a metal supporting frame, filled with broken coke over which water is allowed to trickle. The air, as it passes between the fragments of coke, is thoroughly cleansed of smoke and dust, which is washed down by the water to the bottom of the device and is there removed. Previous to the installation of this plant, drawings, papers, everything, in fact, became very dirty. With the new heating system in service last winter, a remarkable transformation became at once apparent. No air could go into the building except through the heating and washing apparatus, and the slight pressure maintained within doors caused outward leakage at all points where leakage was possible. During the past summer the system was used for ventilation, the heater being thrown out of service, and the result was found to be a clean atmosphere as before, besides a reduced temperature within the building by about 6 degrees as compared with the temperature of the outer air. Pittsburg atmospheric conditions are notoriously bad, so that the successful operation of the apparatus here mentioned is particularly encouraging.

With the recent death of Prof. Franz Reuleaux, in Germany, at the age of seventy-six, the world has lost the greatest machine philosopher of modern times,—one of those scholars whose investigations have added immensely to the stock of common international engineering knowledge, and the results of which have taken

From a Photograph by Reichard & Linder, Berlin.

PROFESSOR FRANZ REULEAUX

firm roots in all countries. There is not room here, in a scant paragraph or two, to tell even superficially of what Professor Reuleaux accomplished in his busy life. For this the reader may be referred to this magazine for December, 1896, in which a condensed, though comprehensive, biographical sketch of him was printed. As his biographer there stated, Franz Reuleaux was a universal genius, epoch-making in his profession, a creator and a leader in the most important domains of human science and knowledge, interested in everything that is noble and great, appreciating all that is eminent among foreign people, a cosmopolitan in the noblest sense of the word.

Several of the automobile periodicals have recently printed emphatic protests against automobile track racing, prompted by the growing list of fatalities and accidents with less serious results which have

been the unfortunate accompaniments of automobile running at high speeds. It is pleasing to note this healthy reaction in such publications, which presumably have some influence among automobile enthusiasts, against the inane desire of many, otherwise sensible, people to break automobile speed records. One of the papers in question invokes the aid of the law in stopping track racing, and refers to a recent afternoon's performance at which ambulances were busily occupied vehicles among the automobiles on the field. The pity of it is only that restrictive measures were not taken long ago against those senseless performances which lead to nothing except broken bones. It is not alone track racing, but road racing as well, that should be put under legal ban. The whole business of automobile racing,—and it is a business of very doubtful propriety,—has not added one particle of useful information to the science of automobile engineering. It has shown, what really was not worth showing, that a freak machine might be run at inordinate speeds by a freak driver.

Some of the worst automobile track race accidents on record have been caused by the whirling clouds of dust in the wake of fast-flying cars, blinding the contesting drivers and causing them to crash into one another or into the rails enclosing the tracks. Perhaps, after all, therefore, the condemnation here of racing may be qualified a bit by saying that the various races have emphasized the dust nuisance which now is the invariable accompaniment of automobile running, and the importance of abating it. It is not the roads alone which are at fault in this matter; automobile builders have much to learn of the art of building a car which will not scour a road in the now usual way. A motor car, like every other object moving through the atmosphere, drags a body of air with it. Even a smooth surface will do this, and it is this air, immediately above the roadway, which is responsible for the dust. In discussing this problem, "The Engineer, of London, points out that the first thing for the automobuilder to do "is to ascertain what form the vehicle should have that will give the minimum volume and velocity to the body of air traveling with it. Probably a parabolic cylinder of some kind would be the best; but no good purpose will be served by basing deductions on the performance of forms which cannot be given to motor cars. Again, it is not clear that the upper portion of a car has any great effect. It is the lower part of the car—the chassis, in fact—on which attention may be concentrated with most profit; and so far it may be taken as proved that the higher the bottom of the car is above the road, and the smoother the surface, the less will be the dust-raising power of the car. Several months ago the Automobile Club undertook and carried out a series of interesting experiments on a specially prepared track at the Crystal Palace. Stive or mill dust was laid down on the track, and cars of various forms were run over this track at various speeds, and the results photographed. The broad conclusion was that cars with flat, smooth bottoms, nearer to the ground at the front than at the back, raised very little dust. The placing of a flat leather sheet under a chassis converted a very bad car into a very good one as far as dust was concerned. Taking it for granted that the underside of the car must be free from projections, it remains to be seen what form of casing shall interpose between the mechanism and the road. Already leather is used in some cars to keep out dust and mud from the machinery. But once the truth has been realized, we shall find that makers will continue to introduce what we may term a dust preventer as an

integral part of the machine. The Crystal Palace experiments went to show that a casing further from the ground at the back than the front gives the best results. * * * The object of the car builder should be so to construct the vehicle that it will pull about with it the smallest possible volume of air at the least possible speed. Careful research is still required to ascertain what is the form of least air resistance—for that is what is wanted—that can be given to a car consistently with the characteristics of a machine-propelled vehicle which it must possess. Enough is known in this direction to make it certain that very little dust is raised by some cars, while others always take clouds of it with them when roads are dry. It remains, therefore, with the purchaser to insist on having a car more or less dustless. If he will follow this policy, there will be small ground for complaint on this score in the future."

Auto-boat racing also has been prolific of accidents; but in its way it has a little more to commend it than the corresponding racing ashore. For example, "this season," says "The Automobile" for September, "has been an unfortunate one for French auto-boats. After the burning of the 'Trefle-à-Quatre,' the sinking of the 'Panhard-Levassor,' and the unhappy ending of the trans-Mediterranean race, now comes the news of the loss of 'La Rapiere.' This remarkable boat was a little more than 26 feet long, and carried a Panhard motor of 100 H. P. She was awarded first prize in the Calais-Dover auto-boat race, covering the 51 nautical miles across the English Channel in 2:25:50. The prize was won on a technicality, however, for the English 'Napier II.' actually made the fastest time, but was disqualified for passing the mark at the finish on the wrong side. The speed of 'La Rapiere' in the Channel race was slightly better than 24 land miles an hour. On August 21 'La Rapiere,' 'New Trefle' and 'Delahaye VI.' started in a 72-mile race on Lake Lucerne for the Lucerne cup. The lead was at once taken by 'La Rapiere' and held until Kastamenbaum was reached, when 'New Trefle' forged ahead, the 'Delahaye VI,' being in third place. In this order they took the turn around Schiller's monument. In passing the rock 'New Trefle' passed so close as to almost graze it. The helmsman of 'La Rapiere' attempted to do the same thing; but he was partly blinded by the spray thrown up by the leading boat and cut in too close, striking the rock with such force as to stave in the bottom of the boat. She at once sank in 650 feet of water. M. Tellier, son of the builder of the boat, and M. Joubert, his mechanic, were rescued by a boat that happened to be near by. Owing to the great depth of water 'La Rapiere' cannot be recovered, and her short and meteoric career is definitely ended."

The existing knowledge of the effects of overheating and rolling at too high a temperature of large steel boiler plates has been added to by an interesting experiment made by one of the large British steel makers, and referred to as follows by Mr. J. T. Milton, chief engineer surveyor to Lloyd's Register, in a paper read at the recent summer meeting of the Institution of Naval Architects:—One large ingot of boiler quality was cut up. Three pieces were rolled into 1-inch plate, one being rolled at what is considered to be the proper temperature, one at too high a temperature, and one too cold. Pieces were also rolled at normal temperatures and too cold into $\frac{1}{2}$-inch and $\frac{1}{4}$-inch plates. The pieces of plates thus made were in some cases overheated and allowed to cool and in other cases they were "nor-

THE PROPOSED BRIDGE OVER THE ZAMBESI RIVER AT VICTORIA FALLS, ON THE RHODESIA RAILWAY. SPAN, 500 FEET; HEIGHT, ABOVE WATER, 400 FEET

malized"—that is, they were heated to bright red and allowed to cool out (the ordinary method of annealing plates); in other cases they had no heat treatment. They were then tested. The results are very interesting and seem to confirm the opinions expressed by the experimenter—namely, that when the steel is initially good, heating the ingot between wider ranges of temperature than should occur in practice with even no more than ordinary care does not have a very prejudicial effect on either the ordinary mechanical tests or even on fatigue tests, the terms "too hot" and "too cold" in these tests referring to such extremes of temperature as would scarcely occur in actual work without very gross carelessness. Further, neither does overheating the finished plates seem to injure them seriously. On the contrary, in some cases it appears to have actually increased their ductility. It must be stated, however, that the experimenter expresses the opinion that in plates where there is considerable segregation the segregated parts might behave very differently under the various heat conditions. Some segregation must exist in all ingots, and therefore also in all plates rolled out of a whole ingot; but when the segregation is slight, seeing that it must occur in the middle of the thickness of the plate near the neutral axis as regards bending stresses, the plates, although inferior to those without segregation, might not be unfit for use.

THE most interesting engineering event of the month just past was the opening of a cantilever bridge across the Zambesi River at Victoria Falls in South Africa on the line of the "Cape-to-Cairo" Railway, by Prof. George H. Darwin, president of the British Association for the Advancement of Science, and in the presence of a goodly number of members of

that association. The bridge crosses the river at a height of a little over 400 feet and is altogether 650 feet long, the span of the arch measuring 500 feet. The gorge of the Zambesi which the bridge crosses is, in many respects, considered to excel the Niagara gorge in grandeur. The Zambesi above the Victoria Falls is about a mile wide and the height of the falls ranges between 400 and 420 feet. When the river is in flood the volume of water going over the falls is estimated to be about double that at Niagara, representing about 35,000,000 H. P., going to waste. The gorge, one of the most remarkable features of the landscape, is cut entirely out of basalt and runs zigzagging for many miles.

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The heavy residue known as masut or astaki, obtained in the refining of petroleum in the Baku district, has of late years become of great importance in Russia as a source of heat, both for raising steam and for heating and melting furnaces in iron works. According to an article in "Stahl und Eisen," abstracted in the volume of "Foreign Abstracts" of the proceedings of the Institution of Civil Engineers, the average composition of masut is, carbon 87.5, hydrogen 11, and oxygen 1.5 per cent., the specific gravity 0.91, igniting point 110 degrees centigrade, and calorific value, 10,700 centigrade units. Although the production is very considerable, being about 47 per cent. of the weight of the crude oil treated, and amounted in 1900 to nearly $4\frac{3}{4}$ million tons, the price seems to increase continually, it having been in that year about eight times that of 1893, while the production had rather more than doubled. As received from the refineries, whether by river or railway transit, it always contains a notable proportion of water which separates slowly by settlement in the storage tanks. The separation is facilitated by making the bottom of the tanks conical, with a water outlet at the lowest point, and supplying the pumps feeding the distributing reservoir through a suction pipe floating on the top of the oil. The final separation of the residual water is effected by steam coils in the reservoir which raises the temperature of the fuel to 60 to 80 degrees centigrade, and gives it sufficient fluidity for the burners. The methods adopted for obtaining an intimate mixture of the liquid fuel and air as a preliminary or combustion may be classified as follows:—1. Evaporation and subsequent mixture by means of air either at atmospheric or higher pressure. 2. Pulverization in special jets or nozzles, either by steam, compressed air, or supplying the oil under pressure.

JOHN VAN VLECK

Mechanical Engineer of the Interborough Rapid Transit Company, New York

A BIOGRAPHICAL SKETCH

By William N. Stevens

PROFESSIONALLY, John Van Vleck is what might be called a constructing electrical engineer. He is, therefore, not only an electrician, but a civil and mechanical engineer as well, besides being an architect. In his capacity as mechanical engineer for the Inter-

borough Rapid Transit Company of New York City, he has been responsible for the design and construction of the buildings and mechanical equipment of the company's now completed subway power station, with its complement of nine substations, all for the generation and distribution of over 100,000 horsepower of energy, the electrical equipment having been designed by L. B. Stillwell, who is the electrical director of the Interborough Company.

Mr. Van Vleck was born in 1864 near the village of Ellenville, Ulster County, New York, his father, John Van Vleck, being at the time a clergyman in charge of a church at Napanoch, having previously held the chair of theology at the Holland Theological Seminary at Holland, Michigan, where Van Vleck Hall still stands as a tribute to his work.

John Van Vleck entered Stevens Institute of Technology in 1880, graduating with his class in 1884. Afterwards he became an employee of the Edison Electric Light Company, at New York, first as a blue printer, and later as a designing draughtsman, in which capacity he assisted in the design of many of the earlier electric light installations. He promptly proved himself to be a competent designer, and he assisted, in no small degree, in the pioneer work of adopting new and better practices in electrical construction. He was one of the first to advocate the concentration of electrical control for power stations, and his early work in this direction was, perhaps, the prototype of the modern switchboard.

From 1886 to 1888 he acted as an inspector of central stations for the Edison Electric Light Company, in which capacity he gained a wide practical experience. In 1888 he was appointed electrical and constructing engineer for the New York Edison Company, a position held by him until 1901, when he was appointed mechanical engineer of the construction department of the New York Subway.

Mr. Van Vleck has been progressive in his ideas and work, in which he has been largely influenced by his contact with foreign engineers during his several tours abroad. He was one of the early advocates of the multipolar direct-connected dynamo and of large multi-expansion engines, and in 1891 his 750-H. P. triple-expansion direct-connected engine was the first of its size and type to appear in this country. Later, he was also the first to complete larger engines, in 1500 and 3000-H. P. sizes, for triple and quadruple-expansion, besides being probably the first to employ a steam pressure of 200 pounds in central station practice. For this high steam pressure it was necessary for him to design a new and special line of steam fittings.

He was also one of the pioneers to propose the adoption of steam turbines for power house work, and as early as 1895 he designed the Twelfth Street Station for the New York Edison Company, which was then intended for steam turbines.

In his work on the design of the Waterside Station of the Edison Company from 1898 to 1901, he adopted poppet-valve construction for the high-pressure cylinders of the engines for employment in connection with superheated steam, the use of which, for several years, he had strongly advocated. Besides his activity in steam engineering, he is the inventor of several forms of electrical apparatus now in use and, apart from the designing of generating and transforming plants, his work has necessarily included much in the way of architectural work and civil engineering in connection with the erection of buildings.

Manufacturing News

SO long as coal remains the basis of industrial progress, any means or methods which result in a reduced cost of coal production must be of interest to all branches of productive industry. Machine methods have long held a prominent place in the coal mining field, and the "puncher" or pick machine is a recognised factor in coal mine economy. But long years of experience with this machine have clearly established its limits of usefulness, and the need of another machine to supplement or assist the "puncher" has long been acknowledged.

A New Coal Cutter

Such a machine is the new radial coal cutter, shown in the accompanying illustration and recently placed on the market by the Ingersoll-Sergeant Drill Company, of New York. While only lately brought before the public, this machine has for a long time been in severe experimental service in some of the largest producing coal mines in the country, and its performance there has aroused the keenest interest among coal mine operators. The radial cutter is designed especially for the work of shearing and entry driving. The idea of the radial mounting is not new, but as applied to the requirements of coal mining it is a distinct innovation, which seems destined to revolutionise certain processes of coal mining, particularly as a means of rapid development.

The economical development of coal properties imperatively demands the use of a shearing machine, but the requirements of the situation were so severe that most devices intended to meet them have been abandoned after discouraging tests. In coal mining catalogues but little has been said, but little information given, on methods of entry driving, on entry-driving machinery, on shearing, drilling, cutting out slate or other bands, and on other economical questions of importance more or less vital to the industry. A machine to meet the conditions properly must be light, simple, durable, and economical of power. It must also be capable of operating with economy of coal, i. e., it must break the coal without producing an unduly large percentage of the smaller sizes.

In operation, the new radial coal cutter has shown itself fully capable of meeting these requirements. As an undercutting machine it is adapted for undercutting headings to any desired depth at a single setting. It will also shear either one or both of the sides of

NEW RADIAL COAL CUTTER BUILT BY THE INGERSOLL-SERGEANT DRILL COMPANY, NEW YORK

an entry, from the floor of the mine to the roof, to any desired depth at one setting. The drill or cutter being mechanically directed, all these operations are performed without any shock or jar on the operator. The machine is light, and easily and quickly moved, and mounted, in this respect also appealing to the man who handles it.

The cut made by the radial coal cutter is 8 feet in depth, and diminishes from a width of $4\frac{1}{2}$ inches at the face to about 2 inches at the bottom. The piston and chuck having a rotating movement, the machine can be used as a drill for putting in the holes preparatory to blasting the coal. This same fact is of value in permitting the use of the machine as a rock drill for "brushing" purposes, and the change from a rock drill to a coal cutter, or vice versa, can be made in a moment of time. It can, therefore, be used advantageously in sinking shafts, driving tunnels in rock, drilling through spars, clay veins, "horse backs," etc.

Its application in the mine materially increases the percentage of lump coal, as well as adding to the output per miner. In mines where the coal is blasted from the solid, this machine may be applied for shearing the rooms in the centre, or for blasting toward the centre upon "open ends." Being mounted upon a plain vertical column, the radial cutter can be raised or lowered to undercut at any point between roof and floor, and readily applied to slate bands, layers of "black jack" and other impurities, leaving the coal mined clean and ready for the market. These are all points which appeal strongly to coal mine operators, especially to those whose output is large and on whose properties a number of entries are to be driven continuously.

An Interesting Oil Test

IN an oil test recently conducted on a 150 H. P. enclosed engine built by the Chandler & Taylor Company, of Indianapolis, Ind., the following results were obtained:—

The engine was made to drive a 100-kilowatt generator both day and night for a week, without a shutdown. Before starting the test the old oil was carefully drawn off and a fresh quantity of high-grade oil costing 60 cents a gallon was accurately measured and placed in the oil reservoirs. The cylinder oil was treated in the same manner. At the end of the week all the oil remaining was drawn off and re-

measured. It was found that the cost of the total amount of oil used by the engine, that is, both cylinder and other lubricating oil, amounted to a fraction less than 75 cents for the entire week, or 168 hours. At this rate the yearly oil bill for an ordinary run, which would be 10 hours per day for 300 days, would amount to $13.39.

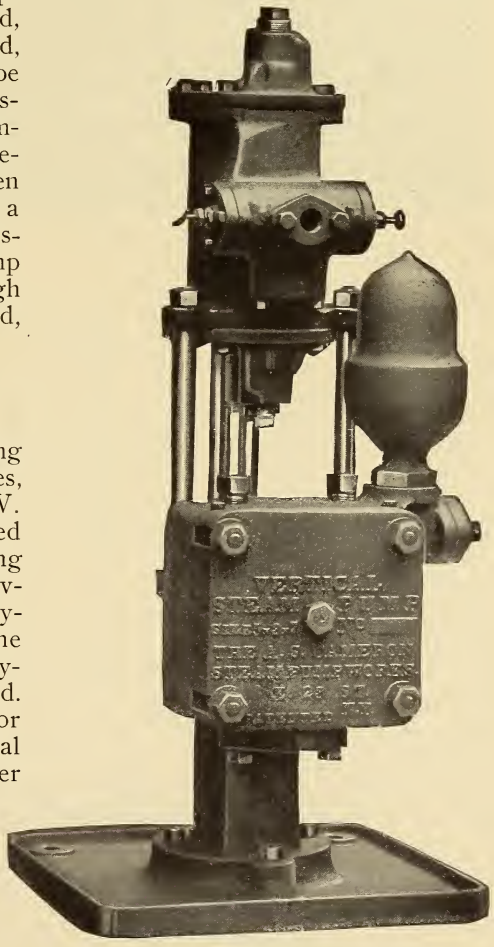
A New Boiler Feed Pump

A NEW vertical boiler feed-pump made by the Cameron Steam Pump Works, of New York, is shown on this page. In common with all Cameron pumps, no working part is exposed except a small part of the rod, which may also be covered, if necessary. The steam end may be adapted to work at any steam pressure; the water end is fitted with Cameron patent primary valves and a removable lining, which may be taken out and replaced with a new one in a few minutes should this become necessary on account of wear. The pump is here shown on a base plate, although it may be bolted in position, if desired, by means of lugs cast on the back.

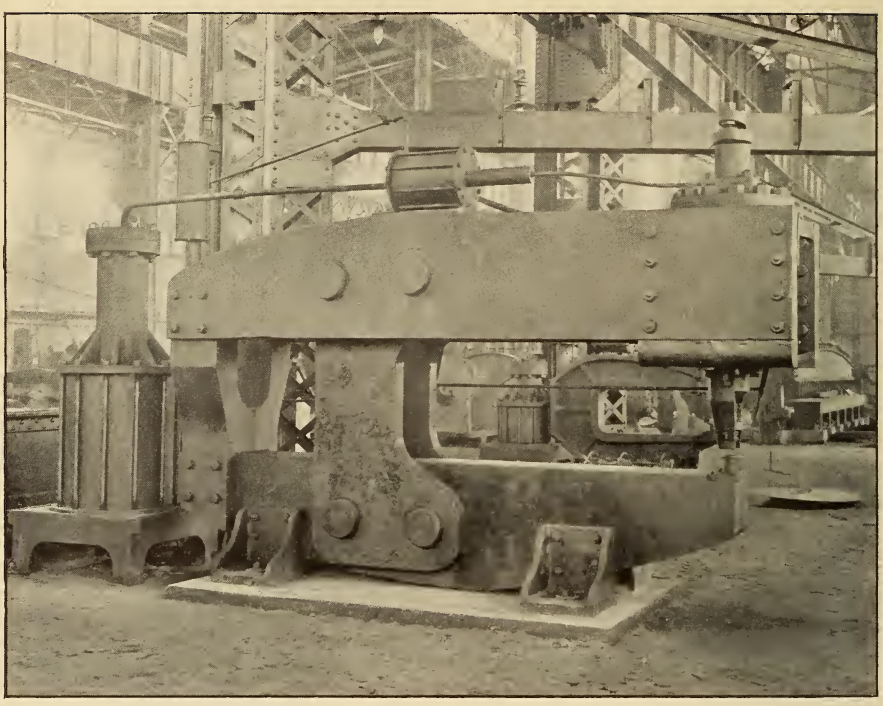
A New System of Operating Hydraulic Machinery

A NEW system of operating hydraulic machinery, — presses, punches, riveters, etc.,—designed by W. H. Wood, of Media, Pa., is illustrated on the two following pages, one of the engravings representing an hydraulic punch, and the other,—in diagram form,—an hydraulic forging machine so equipped. The latter has a 550-ton cylinder for operating the platen, a 110-ton internal clamping cylinder, a 160-ton cylinder in the head of the press, and four 6-inch auxiliary jack clamping rams. The main plunger on the press has a 48-inch stroke, and the plunger in the head has a 36-inch stroke. Hydraulic pressure is applied through the medium of the differential *F* and the low-pressure reservoir *G*, which are controlled by hydraulic valves of a form manufactured by the inventor. A striking advantage is that each of the cylinders in the press can be operated by an ordinary three-way cock, instead of costly valves which are ordinarily used for hydraulic machinery when operated from accumulators and pumps.

This same system has been applied to a number of other machines, including the following:—An 18½-foot gap riveter with multiple cylinders for putting variable pressure on the rivet from 30 to 150 tons, and a plate closer of 30 tons capacity; a 60-inch punch



VERTICAL BOILER FEED-PUMP MADE BY THE A. S. CAMERON STEAM PUMP WORKS, NEW YORK



AN HYDRAULIC PUNCH EQUIPPED WITH WOOD'S SYSTEM, DESIGNED BY W. H. WOOD, MEDIA, PA.

which will punch 4-inch flue holes through $1\frac{3}{4}$-inch plates, and three other hydraulic punches and a shear of varying capacities. This machinery, it has been found, can be worked without hydraulic pumps or accumulators by a series of differentials, and the operating valves and high-pressure mains for conveying the water which are usually used with accumulators and hydraulic pumps can be dispensed with. It is said that the machine can be operated with just as good results as from an accumulator and pump, and without the shocks which usually attend the older arrangement.

For putting the pressure on the water air pressure at 125 pounds is used, which is now commonly available in any boiler shop or bridge works. The tools previously enumerated can all be operated simultaneously from the compressor, which would deliver, say, 1000 cubic feet of air per minute. However, as all the machinery would seldom be in operation at one time, only a portion of this quantity of air would be required.

In working the press under this system, as compared with the accumulator and pump system, one great advantage is that the platen may be moved from the low-pressure water reservoir with the 125 pounds pressure due to the air on top of the water until the high pressure is required for the effective stroke, which is usually only about 30 per cent., or even less, of the stroke. In the accumulator system the whole movement of raising the table until the work is accomplished would have to be done with 1500 pounds pressure; consequently, there is a large saving in the new arrangement, where one-twelfth of the maximum pressure can be used for practically 70 per cent. of the movement of the table.

With the practicability of the system assured, there would remain little doubt of its general adoption for operating the various types of hydraulic machinery.

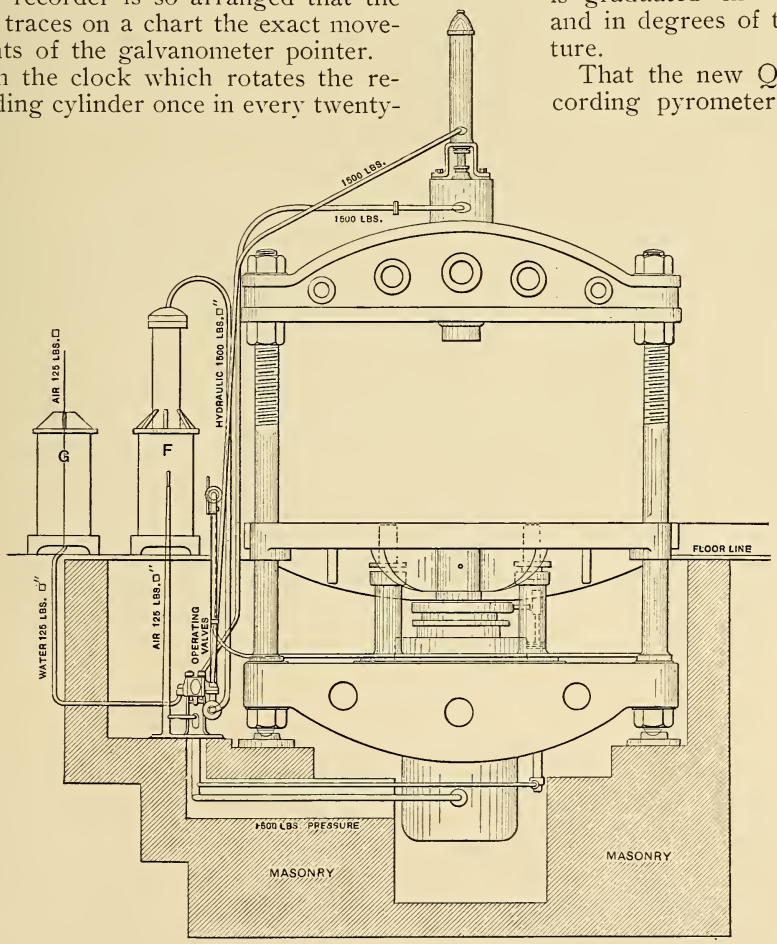
Instantaneous Record of High Temperatures

A VALUABLE addition to the recording instruments made by Queen & Company, Inc., Philadelphia, is their new recording pyrometer for high temperatures. This instrument is the result of a number of experiments, and embodies in its construction many novel and valuable features. It is adapted to give a continuous record of temperatures up to 3000 degrees F. The galvanometer, especially designed for this purpose, is of the D'Arsonval type, and besides presenting the important feature of extreme sensitiveness, is absolutely dead beat. It is, moreover, not in the least affected by vibrations. The recorder is so arranged that the pen traces on a chart the exact movements of the galvanometer pointer.

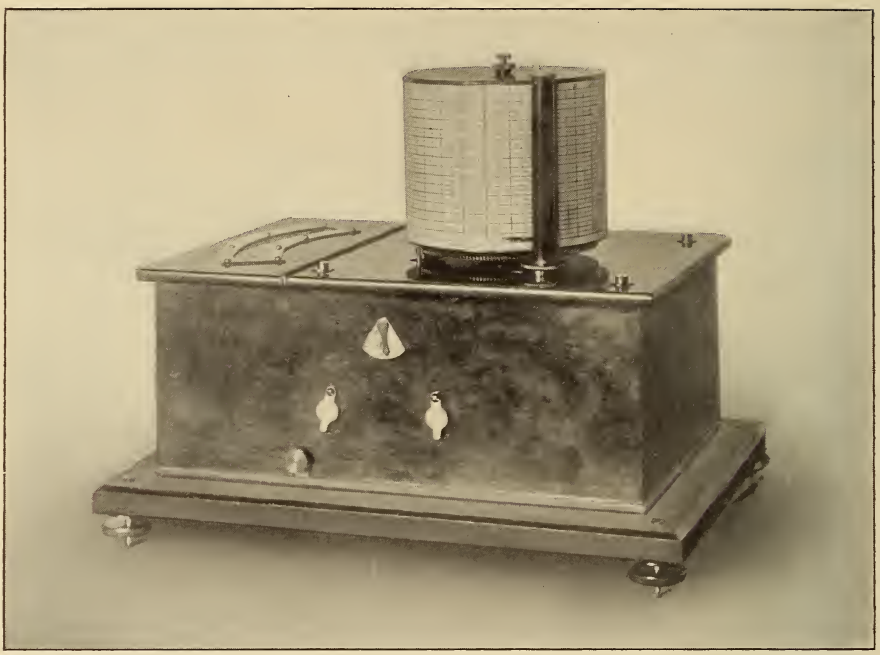
In the clock which rotates the recording cylinder once in every twenty-four hours, an electric contact is made every minute; this causes an electromagnet to be energised which clamps the pointer of the galvanometer. This pointer in turn operates a relay, causing the pen to move up and down until it coincides with the reading of the galvanometer. The pointer then swings entirely free until the next contact is made. The recording device in no way impairs the accuracy or sensibility of the pyrometer.

The thermo-electric couple consists of platinum and platinum-rhodium wires three feet long, enclosed in a porcelain protecting tube. Any desired length of wire will, however, be furnished. The indicating instrument is graduated in millivolts and in degrees of temperature.

That the new Queen recording pyrometer is por-



THE WOOD SYSTEM APPLIED TO A FLANGING PRESS



A NEW RECORDING PYROMETER, MADE BY MESSRS. QUEEN & CO., INC., PHILADELPHIA

table, and that it gives a continuous record for the whole twenty-four hours, are points of too great importance to be overlooked.

The Solvay Process Company, Syracuse, New York, and the William Wharton Company, of Philadelphia, have recently purchased the new Queen recording pyrometers for their works.

A New Boiler Feed Pump

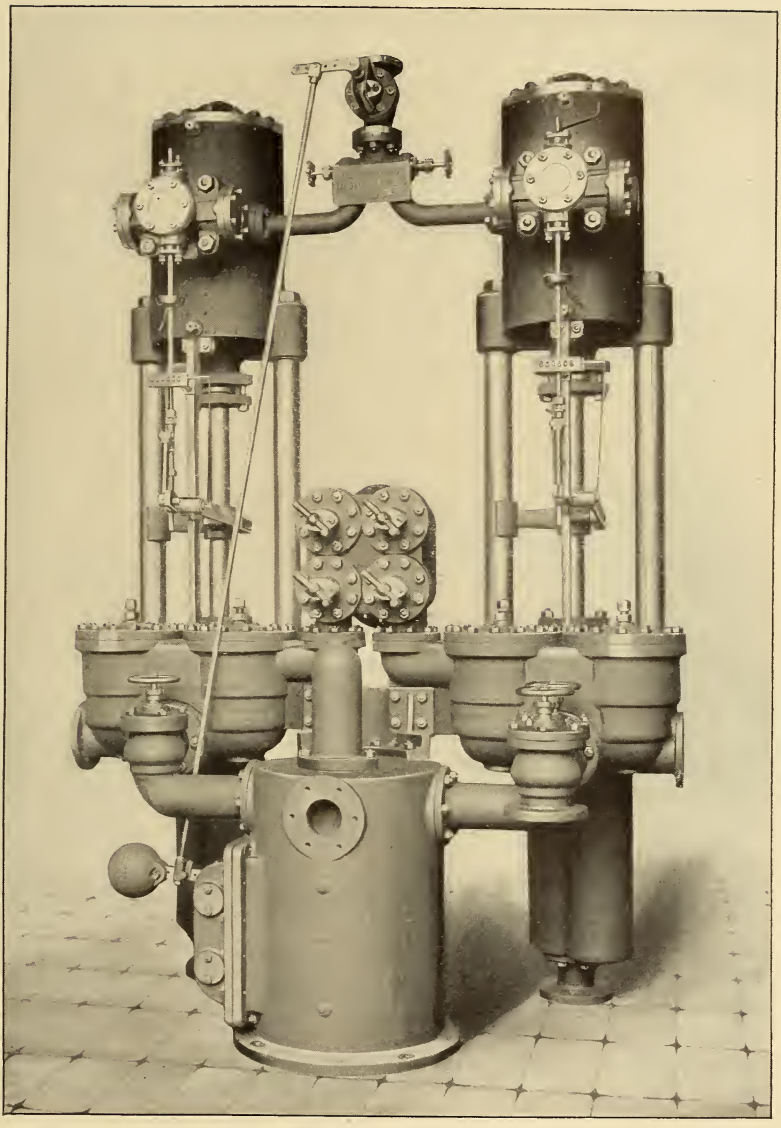
ATTENTION is called to the twin boiler-feed pump, shown herewith, as a representative type made by the Dean Brothers Steam Pump Works, of Indianapolis, Ind. This pump is designed for pumping hot water against heavy pressure, and is intended for use in electric power plants, marine service, or wherever a high-pressure boiler-feeding outfit may be required.

The pumps here shown are arranged for automatically taking water from a hot well in connection with surface condensers. Either of them will work equally well singly. The hot well is fitted with a float which connects with the steam valve in such a way that the water is maintained at a certain desired level.

All the steam joints are made with socket and spigot so as to hold the gaskets permanently. The water valves are grouped in nests, and both valves and seats can be lifted out of the cylinder whenever desired. Solid bars of rolled Tobin bronze are used for making the valves, and phosphor bronze is used for the valve seats. Those parts subject to wear or to severe strain are made of steel.

A New Battery Charging Device

A RECENT development as a part of electric vehicle-charging equipments made by the General Electric Company, of Schenectady, N. Y., is a mercury-arc rectifier for converting alternating into direct currents. The rectifier depends for its operation on the now well-known property of vapor tubes by which cur-



A NEW TWIN BOILER FEED PUMP MADE BY THE DEAN BROTHERS STEAM PUMP WORKS, INDIANAPOLIS, IND.

rent is allowed to flow in one direction only, the electrodes acting as electric valves. An alternating current, then, may be "rectified" into a pulsating direct current by the suppression of the flow in one direction.

A great advantage claimed for the mercury-arc rectifier is that it gives a higher efficiency and power factor than a motor generator set, as well as a lower first and operating cost. The outfit is furnished in three capacities, 10, 20 and 30 amperes, and can be adapted to any commercial alternating-current voltage and any direct-current voltage necessary for charging vehicle batteries. It can be furnished for any commercial frequency.

A New Radial Drill

THE American Tool Works Company, of Cincinnati, Ohio, recently brought out the new 3-foot arm combination radial drill shown in the accompanying illustration. It is built with either cone pulley or speed box drive. The range of feed is from 0.007 inch to 0.041 inch, and is obtained by turning a dial on the feed box, which latter provides four changes. The spindle has eight changes of speed. The operating levers are all placed so as to be within easy reach of the operator at the front of the machine.

NEW RADIAL DRILL BUILT BY THE AMERICAN TOOL WORKS CO., CINCINNATI

A New Water-Tube Boiler

THE advantages claimed for the water-tube boilers made by the Henry Vogt Machine Company, of Louisville, Ky., are general efficiency, accessibility for cleaning and inspection, steadiness for water level, rapid circulation, dry steam, and durability. There are two upper steam and water drums extending the entire length of the boiler, which provide a large storage capacity for steam and so help to prevent sudden fluctuations in pressure. At the front they are connected with a cross drum, and at the rear end, headers are riveted to them. By means of a double row of vertical tubes these headers are connected to a mud drum which is attached directly to the lower rear cross drum.

This is connected with the front twin cross drum by an inclined bank of tubes, and the front and rear twin cross drums are similarly connected with the upper front cross drum, thus completing the circuit that the water and steam must travel before reaching the steam drums.

The construction of the boiler is claimed to be such as to avoid rigidity, each member being free to expand without putting undue strain on any other member or loosening any of its parts or connections.

The arrangement of the tubes introduces several large combustion chambers between each bank of tubes, which, being surrounded by red hot fire tiles, is claimed to insure an almost perfect combustion of the gases before reaching the chimney. The hot gases travel three times the length of the boiler and then finally descend and pass over the vertical rows of tubes in the rear of boiler through which the feed water descends to the mud drum.

New Trade Catalogues

IF, in the making of books there is no end, surely in the making of catalogues there is none. The 1905 editions of trade catalogues are apparently more numerous and more varied in their design than ever before. Some cover their subjects in a few pages, while others are almost text books with much valuable information. Many of them are found on the shelves of our best technical libraries, where they are often consulted in preference to encyclopedias as being more up-to-date and clear in detail.

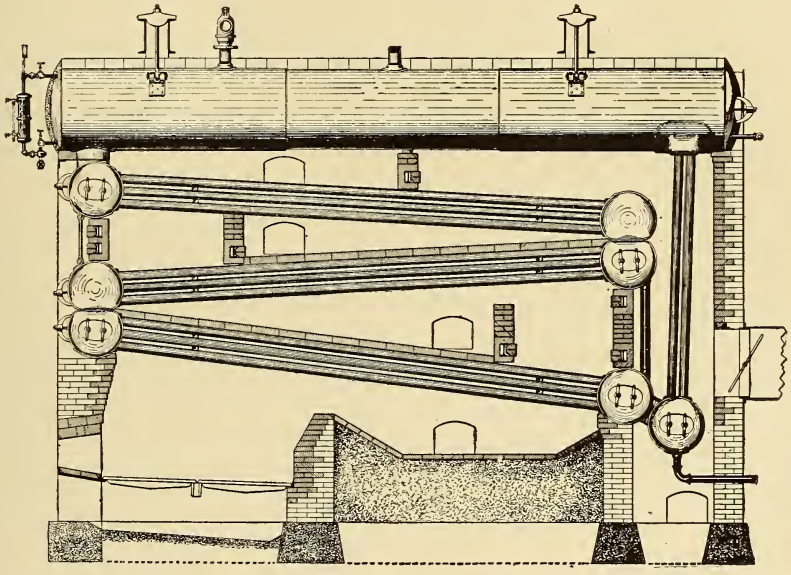
Among the more attractive of the present collection of catalogues is that

of the Hayward Company, of New York, entitled "Digging Machinery." There are over 100 pages in this catalogue, about one-third of which are devoted to illustrating and describing the construction of orange-peel and clam-shell buckets. There are two views of each type, showing the bucket closed and open. The remainder of the catalogue is devoted to illustrating and describing the various dredges, derricks, excavators, and cranes equipped with Hayward machinery. In each case the machinery has been photographed in action, making the reproductions particularly picturesque and interesting.

The thirty years' experience of the Ingersoll-Sergeant Drill Company, of New York, have enabled them to incorporate in their catalogues a vast amount of invaluable material relating to air compressors and coal-mining machinery. Numerous illustrations and descriptions, together with useful tables and information regarding the use of compressed air and coal cutting and drilling machinery, make these catalogues particularly valuable ones. In a separate bulletin they present the MacDonald rivet forge, which is operated by compressed air.

"Unit Accumulator" is the title of an attractive catalogue on electric storage batteries, brought out by the National Battery Company, of Buffalo, N. Y. The details regarding the construction of each type are fully presented by aid of illustrations and tables.

The Borden & Selleck Company's three catalogues devoted to conveying and elevating machinery are also among the newcomers. This Chicago firm has gone to considerable expense in thoroughly illustrating nearly every detail of their products, and many installations in which the Harrison conveyors made by them form important parts, are pictured and described.



A NEW WATER TUBE BOILER, BUILT BY THE HENRY VOGT MACHINE CO., LOUISVILLE, KY.

The Newton Machine Tool Works, of Philadelphia, in a catalogue entitled "Vertical Mining Machines," illustrate and describe these products.

A very attractive catalogue describing and illustrating the double magazine Mergenthaler linotype machine has been issued by the Mergenthaler Linotype Company, of New York.

Front and rear views of the assembled machine are first shown, then the various details are pictured and explained separately, and finally a number of specimens of composition done on the machine is shown. These specimens are most creditable productions.

A very complete and attractive catalogue on steam turbines and electrically driven centrifugal pumps has been brought out by the De Laval Steam Turbine Company, of Trenton, N. J. Besides a number of well-executed illustrations, the catalogue contains descriptions and results of tests on different types of De Laval pumps.

The J. A. Fay & Egan Company, of Cincinnati, Ohio, announce in a neat-looking pamphlet their list of second-hand woodworking machines in stock to date.

The Wellman-Seaver-Morgan Company, of Cleveland, Ohio, attractively illustrate and describe the Dewhurst slag ladles and cars in a new catalogue.

A new catalogue sent out by the Fischer Foundry & Machine Company, of Pittsburgh, illustrates and describes rolling mills, power shears, bending and straightening machines, and tube mill machinery. A number of hydraulic machines is also shown, including shears, presses, and riveters, together with hydraulic intensifiers and accumulators.

The Allis-Chalmers Company, of Milwaukee, are represented by two handsomely designed and illustrated catalogues, one giving particulars of the Reynolds Corliss steam engines and the other of machinery for cement making. Both these catalogues are typical examples of high-class advertising literature.

This may also be said of the catalogue issued by the Sullivan Machinery Company, of Chicago, entitled "Modern Practice in Air Compression." In many respects this catalogue surpasses certain text books on the subject, being profusely illustrated, well written, and fully indexed. In addition to descriptions of Sullivan compressors, practical suggestions for erecting and operating them are given in this publication. In a separate bulletin they present their straight-line steam-driven air compressor.

The J. G. Brill Company, the well-known car builders of Philadelphia, have also sent out a very attractive catalogue illustrating and describing in detail their No. 27-E truck, and another treating on supplies and car specialties.

Another catalogue on railway machinery is that entitled "Balanced Compound Locomotives," issued by the Baldwin Locomotive Works, of Philadelphia. This gives a record of recent locomotive construction.

The Guarantee Electric Company, of Chicago, have issued a pictorial catalogue entitled "As the Photographer Saw Us." The series of illustrations contained in it afford an excellent idea of the various departments in their well-equipped establishment. The firm deal in dynamos and motors, both new and second-hand apparatus, and invite attention also to their testing and repair departments.

A new catalogue of the Brown & Sharpe Manufacturing Company, Providence, R. I., is cloth bound and of convenient pocket size. It is well illustrated and gives much valuable information on milling, grinding, automatic gear cutting, and screw machines; also on cutters, accurate test tools, and machinists' tools. This little volume is fully indexed, has 494 pages, and contains many tables that will be found useful by machinists and engineers.

The Gisholt Machine Company, of Madison, Wis., present their vertical boring and turning mills and their horizontal mills, in a very neat and attractive catalogue. The illustrations and press work in this publication are excellent.

"Gas Producers and Gas Engines" is the title of an interesting catalogue brought out by the Weber Gas & Gasoline Engine Company, of Kansas City, Mo.

Milling machines are treated of in

the catalogue of the Kempsmith Manufacturing Company, of Milwaukee, Wis., in which are given illustrations and dimensions of the various designs turned out by them.

The Lidgerwood cableway, a hoisting and conveying device, made by the Lidgerwood Manufacturing Company, of New York, and employed in the construction of canals, dry docks, dams, piers, and fortifications, also in quarrying and discharging vessels, is thoroughly illustrated and described, together with its applications, in a massive catalogue of 160 pages.

A catalogue presenting the full line of tools manufactured by the Fox Machine Company, of Grand Rapids, Mich., for pattern shop equipment, is worthy of mention. The illustrations are numerous and well executed, and the descriptive matter is neatly arranged.

The Watertown Engine Company, Watertown, N. Y., builders of engines and boilers, advertise these very attractively in a new catalogue. The press work is exceptionally well executed.

Equally neat and attractive is the catalogue brought out by the C. W. Hunt Company, of West New Brighton, N. Y., in which the Hunt noiseless conveyor and other machinery for handling coal and ashes in power stations are presented. This publication abounds in numerous illustrations, which show not only the various machines built by the Hunt Company, but also the installations in which they are employed.

"A Study of the Adams-Farwell Motor Car" is the title of a well written and illustrated publication brought out by the Adams Company, of Dubuque, Iowa. By carefully reading the descriptions of the various parts of this motor car and the instructions given for operating and caring for it, one feels perfectly acquainted with the car and appreciates its many excellent features. Either four or seven persons may be comfortably carried, according to the style of car selected.

The A. D. Granger Company, of New York, have interesting matter to present to the man who burns the coal and the man who pays the bills, in the way of Vulcan shaking and dumping grates, stationary grates of all patterns, cast-iron boiler fronts, steel-plate boiler fronts, and other boiler castings.

In Part II. of the general catalogue issued by Warren Webster & Co., of Camden, N. J., is presented the Webster feed-water heater and chemical purifier,—a self-contained device for preventing corrosion or scale in steam boilers.

The catalogue of the Corliss Engine Works, of Philadelphia, contains illustrations of the Rickards' Corliss steam engines, together with a general description of their various working parts. Several pages of testimonials and a list of the users of these engines are also included.

Alberger high-vacuum apparatus, especially adapted to vacuum pans, evaporators, and stills, also to condensers, cooling towers, pumps, and turbines, are treated of in an attractive catalogue issued by the Alberger Condenser Company, of New York. As stated in the catalogue, this company are prepared to make surveys of plants, furnish drawings, plans, specifications and estimates, and also to contract for condensing apparatus and its appurtenances for all kinds of service.

The Jeffrey Manufacturing Company, of Columbus, Ohio, will issue from time to time bulletins giving descriptions of installations in which their mining, elevating, or conveying machinery is employed. The first of these bulletins has made its appearance, and treats of the coal and ashes distribution plant of the Scioto Valley Traction Company, at Reese's Station, Ohio.

Williams, White & Co., of Moline, Ill., have issued a catalogue of over one hundred pages of useful information regarding the forging, punching, shearing, and hydraulic machinery manufactured by them. The numerous and varied types of machines de-

signed and built by this concern, all of them illustrated in the catalogue, attest to the excellent facilities they possess for turning out satisfactory work.

The April number of "The Progress Reporter," a publication issued every few weeks by the Niles-Bement-Pond Company, of New York, to keep the employees of the company and the public generally informed as to the new machines and devices brought out by this concern, is particularly interesting. The Niles-Bement-Pond Company build everything in the way of machinery for locomotive shops, from the electric travelling crane which can pick up the heaviest engine, through the entire list of metal-working machinery to the precision hand tools and gauges. In the publication mentioned, over forty illustrations of the American Locomotive Company's works, at Schenectady, testify how extensively the Niles-Bement-Pond machinery is employed by this company.

"A Book on Steam for Engineers" is the expressive title of a 248-page book just sent out by the Stirling Company, of Barberton, Ohio, makers of the Stirling water-tube boiler. It contains a detailed description of the boiler, with numerous illustrations, followed by a mass of miscellaneous information on such subjects as the advantages of water-tube over fire-tube boilers, heat, air, water, and impurities, and heating of feed water. In the section devoted to steam, tables of steam properties are given. The Stirling superheater is illustrated and described, and the calorific value of different fuels is discussed. Coal, oil, wood, natural gas, and "bagasse"—refuse sugar cane—are thus taken up. The book is well bound in cloth and presents an attractive appearance.

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